Electrical Engineering

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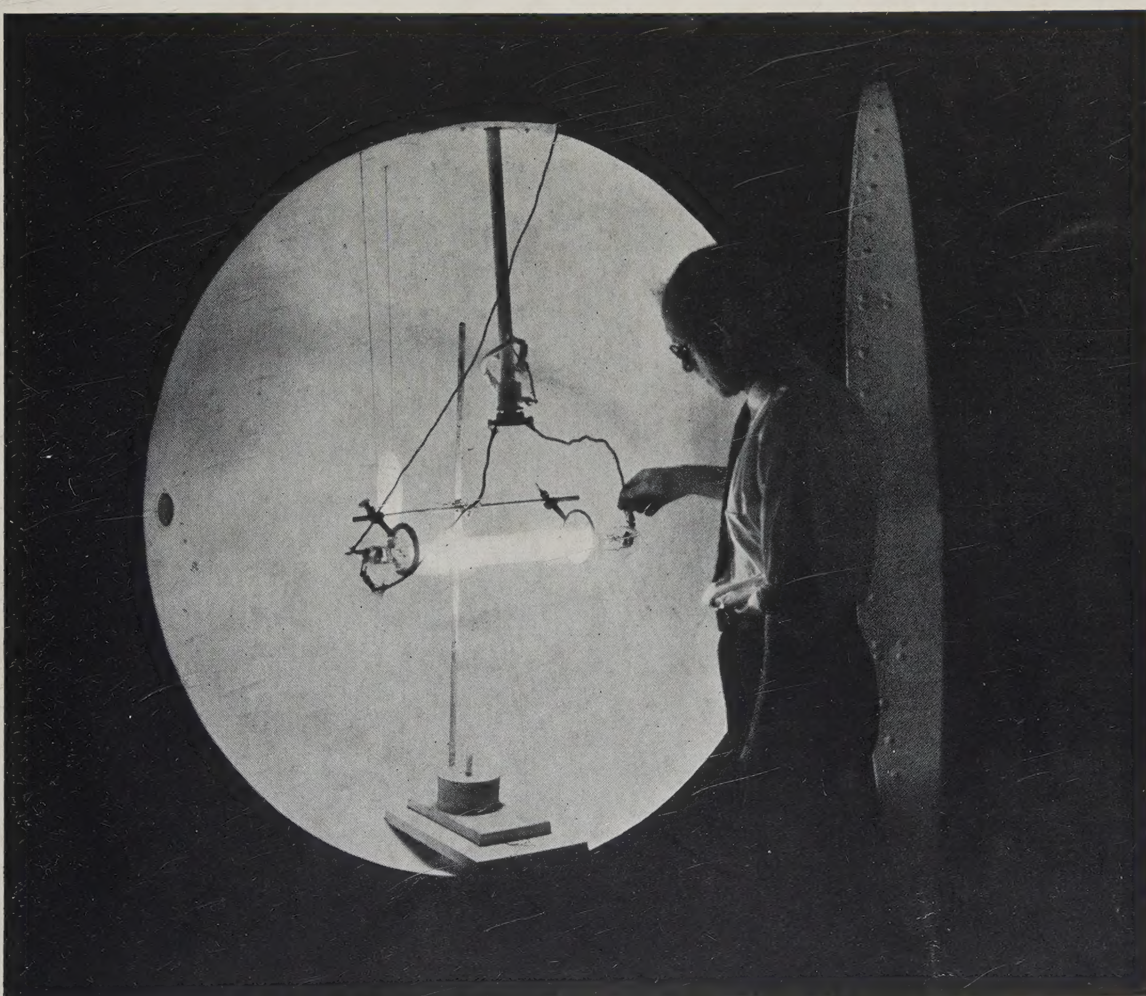

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Future Meetings of the American Institute of Electrical Engineers

Place	Date	Nature	Manuscript Closing Date
Schenectady, N. Y.	May 10-12, 1933	District Meeting	Feb. 10, 1933
Chicago, Ill.	June 26-30, 1933	Summer Convention	March 26, 1933
Salt Lake City, Utah	Aug.-Sept. 1933	Pacific Coast Convention	May-June 1933

NOTE: Members who are contemplating submitting papers for presentation at any of the above meetings should communicate promptly with Institute headquarters, 33 West 39th Street, New York, N. Y., so that such papers may be docketed for consideration by the technical program committee, which formulates programs for all meetings several months in advance. Upon receipt of this notification, Institute headquarters will mail to each prospective author important and helpful information explaining the Institute's rules relating to the preparation of manuscript and illustrations.

Future Meetings of Other Technical Organizations

Society and Nature of Meeting	Place	Date	Correspondent
American Concrete Institute, annual meeting	Chicago, Ill.	Feb. 21–24	
American Institute of Mining Engineers, annual meeting	New York, N. Y.	Feb. 20–23	A. B. Parsons, Secy., 29 West 39th St., New York, N. Y.
American Physical Society	New York, N. Y.	Feb. 23–25	W. L. Severinghaus, Secy., Columbia Univ., New York, N. Y.
American Physical Society	Washington, D. C.	Apr. 27–29	W. L. Severinghaus, Secy., Columbia Univ., New York, N. Y.
American Physical Society, Pacific Coast meeting	Salt Lake City, Utah	June 16–19	L. B. Loeb, Pacific Coast Secy., Univ. of Calif., Berkeley, Calif.
American Physical Society	Chicago, Ill.	Week of June 19	W. L. Severinghaus, Secy., Columbia Univ., New York, N. Y.
American Society of Civil Engineers	Miami, Fla.	March 27–31	G. T. Seabury, Secy., 29 West 39th St., New York, N. Y.
American Society of Mechanical Engineers	Chicago, Ill.	June 26–30	C. W. Rice, Secy., 29 West 39th St., New York, N. Y.
American Society for Testing Materials	Chicago, Ill.	June 26–30	Am. Soc. for Testing Mtls., Phila., Pa.
Engineering Institute of Canada, annual meeting	Ottawa, Ont., Canada	Feb. 7–8	
N.E.L.A., New England Div., Engg. Section	Boston, Mass.	March 2–3	O. A. Bursiel, 20 Providence St., Boston, Mass.
N.E.L.A., Natl. Engg. Section, group committee meeting	Detroit, Mich.	Apr. 10–14	A. H. Kehoe, Chmn., New York Edison Co., New York, N. Y.
Oklahoma Utilities Assn.	Oklahoma City, Okla.	March 7–8	E. F. McKay, 1020 Petroleum Bldg., Oklahoma City, Okla.

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This Month—

Front Cover

A sodium-vapor lamp set up for test in a spherical photometer. This new light source has an efficiency several times that of the ordinary incandescent lamp; it is applicable wherever monochromatic radiation is required, in spectacular lighting, and in the immensely wider field where cheaper light is demanded.

General Electric Company Photo

CORRECTION—The cuts for Fig. 6 and Fig. 7 on p. 32 and 33 of ELECTRICAL ENGINEERING for January 1933 should have been interchanged. These figures appeared in "Pipe Line Pumping and Automatic Control," by John Fies.

OPERATION of the 3,000-volt d-c electric locomotives in use on the Cleveland Union Terminals electrification, has been highly satisfactory. More than 1,000,000 miles of operation have been recorded, with only 6 electrical failures. *p. 96–9*

ELECTRIC power for the Pennsylvania's electrified line between New York and Philadelphia is supplied through substations in which has been installed initially 1,280 kva capacity in step-down transformers per route mile of railroad. Arrangement of apparatus and circuits adopted has resulted in many advantages. *p. 111–15*

BALANCING of a composite submarine telegraph cable requires first an intimate knowledge of the terminal impedance characteristics of the cable. In an article prepared especially for ELECTRICAL ENGINEERING by Dr. M. I. Pupin, one of the Institute's 8 honorary members, the impedance characteristics of a composite cable are shown to be similar to those of a uniform cable. *p. 115–18*

A REPORT of the Institute's recent winter convention held in New York, N. Y., January 23–27, 1933, is included in this issue, including a full report on the Edison Medal presentation, abstracts of most of the addresses presented at technical sessions, board of directors meeting, and the various entertainment features. p. 125–32. Abstracts of all 58 technical papers are included in the January 1933 issue, *p. 41–52*, and in this issue p. 122–4.

MANY ADVANCES in insulation research during the past year were reflected in papers and discussions presented at the annual meeting of the committee on electrical insulation of the National Research Council held during October 1932. Summaries of these sessions have been prepared by the chairman and vice-chairman, respectively, of that committee; these are published in this issue as well as author's abstracts of the various papers presented. *p. 99–106*

DIRECT SELECTION supervisory control, by means of single direct-acting impulses from control switches at the dispatching office, connects the line wires almost instantly to the apparatus to be operated at the remote station. No time is lost in connecting the line wires to points where they are not to be used. *p. 81–4*

AIR CONDITIONING in railway passenger cars required the development of apparatus quite different from ordinary commercial air conditioning equipment. This apparatus must be not only light in weight and reliable, but also easily accessible for inspection and repair. *p. 85–8*

FROM the results of extended impulse and dynamic power-follow flashover tests on typical 26-kv wood pole construction for electric power transmission lines, the flashover voltages of wood and porcelain combinations of simple pole tops can be estimated. It is now possible to design a wood pole line with almost any practical degree of lightning reliability. *p. 89–95*

SEVERAL successful installations in different branches of industry testify to the superiority of electronic control devices over the more conventional electromechanical control. Electronic equipment is adaptable to almost any control problem that the industrial engineer may face. *p. 106–10*

The Battle of the Alchemists

By KARL T. COMPTON

President, Massachusetts Institute of Technology, Cambridge, Mass.

Herewith is presented a review of Man's accomplishments in the transmutation of the elements of our physical world, from the time of ancient mythology when the alchemists sought to transform lesser substances into gold and silver, down to the time of our present-day alchemists, the modern physicists. The goal of today's battle is not precious metals, but energy.

LONG, LONG AGO, when gods mingled among men, the god Hermes established the first laboratory on this earth and discovered many new and interesting substances by subjecting various kinds and mixtures of earth and rocks to the influence of fire or water. Not being blessed with the protection of the United States Patent Office, he kept his discoveries secret by putting his products into jars which were carefully closed and sealed. Hence arose the term "hermetically sealed," and the chemistry and metallurgy which thus sprang from the god Hermes was long known as the "hermetic art."

According to another legend, a group of wicked angels were expelled from heaven and settled on the earth, taking unto themselves human wives. To these wives the fallen angels disclosed the magic secrets of science, and the wives recorded these secrets in a book which was called "Chemna,"—the first handbook of chemistry. Thereafter those who practiced this art were called "alchemists." The ancient historian Tertullian tells of these fallen angels who thus revealed to mankind the knowledge of gold and silver, precious stones, and medicines.

However these things may be, there is ample documentary evidence from Egypt that alchemy was a flourishing science and art in Alexandria before the third century A.D., and it is probable that a famous book whose destruction was ordered by Diocletian in about 290 A.D. was one containing receipts and formulas for producing alloys to simulate gold and silver and for manufacturing artificial jewels.

These early alchemists, like modern chemists, were guided by a theory. Like our modern theories, theirs was imperfect and like ours it was an attempt to interpret and predict on the basis of a generalization of experience. They started with Aristotle's conception of 4 fundamental elements—earth, water, air, fire. These are not so different from, for example, the notion of the 4 states of matter proposed by Sir William Crookes, the solid state, the liquid state, the gaseous state, and the ionized state. The alchemists also believed that there was one basic entity, *prima materia*, which was identical in all bodies, but which took different forms according as it was brought into combination with one or more of the fundamental elements, earth, water, air, and fire. In our time, we recognize this *prima materia* to be electricity existing in 2 forms, electrons and protons. By action of earth, water, air, or fire on the various manifestations of the *prima materia*, these alchemists performed oxidation, reduction, solution, smelting, alloying. It is not to be wondered that they interpreted their work as a "transmutation of matter"; from their standpoint it was transmutation.

On account of the variety of colors which the compounds of mercury and sulphur exhibit, and their ease of chemical change, it is not surprising that those elements were of particular interest to the alchemists, and were supposed to be quite close to this *prima materia* which they sought. It is not so easy, however, to understand their choice of some of the other substances. For example, in the year 1250 Beauvais classified matter as consisting of 4 spirits and 6 bodies: The 4 spirits were mercury, sulphur, arsenic, and sal ammoniac; the 6 bodies were gold, silver, copper, tin, lead, and iron, of which gold and silver were pure and the rest impure.

In addition to this Greek background, which was gropingly scientific in its approach, the mystery and magic of the Orient were introduced from Arabia, Persia, and India as a result of the various wars and invasions. Thence came the notion of the "philosopher's stone" whose magic touch would transform common substances into gold. The philosopher's stone, perhaps, should be thought of as the first catalyst except that it was like the fountain of youth or the end of the rainbow, or the Utopia—only a beautiful product of the imagination.

In the rapid rise of chemistry during the 19th century, a beautiful and nearly perfect scientific theory of atoms and molecules was developed as a far extension of the ancient philosophical ideas of atoms advanced by Democritus. How sound was this theory, was demonstrated by the fact that it was only extended, but not essentially changed, when physicists devised methods of counting and weighing molecules individually, measuring their separate velocities and the energy and force required individually to pull them apart into their constituent atoms. The puzzles of the old alchemists were solved by the recognition of 2 classes of substances, elements and compounds, of which the former retain their identity throughout all action of earth, water, air, fire, or any other physical or chemical agent. Thus alchemy, which sought to transmute the elements, became supplanted by chemistry, which occupied itself with the various combinations of these elements to form chemical compounds. "Alchemy was dead: Long live chemistry!" But is this the end of the story?

Full text of the 7th lecture in the series of Steinmetz memorial lectures delivered before the A.I.E.E. Schenectady (N. Y.) Section, Nov. 18, 1932. *Pamphlet copies not available.*

The textbook in which the author first studied chemistry in 1904 defined an atom as "an indivisible, indestructible, and unchangeable unit of matter." Yet 5 years *earlier* J. J. Thomson and his colleagues had split up atoms into electrons and positive ions and within 20 years it had come to be realized that the atom could be very changeable—could in fact exist in any one of an infinitely infinite variety of conditions commonly termed "excited states." Thus the atom is *not* indivisible and is *not* unchangeable, but these changes do not really affect the identity of the atom: the electrons which it loses come back to it or others take their places; it does not stay in its excited states very long, but reverts to its normal state usually within a hundred millionth of a second.

We must not despise the efforts of the early alchemists. Among them were numbered such great minds as Newton, Leibnitz and Boyle, all of whom studied and practiced alchemy, though they were beginning to realize its defects. But from this mixed ancestry of legend, experiment, and magic was born the science of chemistry!

In its ionization and its excited states the identity of the atom is like that of a man. You may cut off his hair or his nails, but they come back. You may even amputate a finger or a leg, but he is still the same man. Or you may excite him to a fit of anger or activity, but he cools down again. Through it all he retains his identity by virtue of that mysterious something that we call his soul. Now the soul of an atom is its nucleus. Through ionization and excited states this nucleus, so far as we know, remains unchanged. Until we know the nucleus of the atom we no more know the atom than do we know a man by his hair, nails, fingers, or legs. What do we know about the nucleus?

Beyond a doubt we know exactly the mass of every kind of atomic nucleus; we know that it is composed of a definite number of protons and electrons, and that it has a positive electric charge, which we know accurately. Thus the hydrogen nucleus consists of a single proton; the helium nucleus consists of 4 protons and 2 electrons and has a mass 0.77 per cent less than the sum of 4 hydrogen nuclei; the uranium nucleus consists of 238 protons and 146 electrons, etc. We know also that the nucleus is very small in comparison with the over-all atomic dimensions, i. e., much smaller than 10^{-10} cm in diameter—probably less than 10^{-11} cm.

We have good reason for thinking that some atomic nucleuses are magnets with a magnetic moment equal to that of one electron, and that this is true if there be an odd number of electrons in the nucleus. But some phenomena have not as yet been reconciled with this idea of the magnetic properties of the nucleus. Furthermore, there is reason to believe that the proton configurations in the nucleus also may contribute a magnetic moment, far smaller than that due to the electrons.

We know that atomic nucleuses are deformable under the action of intense forces, such as can be exerted only by electrified particles like alpha particles from radium, which are shot toward the nucleuses with such tremendous velocities that they may come very close before being deflected away by the repulsive force between nucleus and alpha particle. When their distances are greater than 10^{-10} cm this force varies inversely as the square of the distance, as nearly as we can tell; this shows us that the nucleuses are practically electrified points as far as distances greater than 10^{-10} cm are concerned. With closer approach, however, the force departs more and more from the inverse square law, showing that the nucleuses have a structure or arrangement of electricity within their tiny domains, and that this structure may be deformed by strong electrical forces. All of this information is inferred from studies of the angular distribution of scattering when alpha particles pass through thin films of matter.

We know that the nucleuses are seats of tremendous energies, as evidenced directly by phenomena of radioactivity and indirectly by certain aspects of the theory of relativity to which I will refer later. From radioactivity, also, we find that groups of 4 protons and 2 electrons (helium nucleuses) appear to be particularly stable configurations within the larger structure of the nucleuses of heavy atoms. We call these groups "alpha particles."

The atom is still the same old atom; and while its new attributes discovered by the physicists add to its versatility, they do not undermine its fundamental character of good old-fashioned chemical respectability.

Having said these things, we have told almost everything that is known about atomic nucleuses. Many other things we would tremendously like to know. How are the protons and electrons arranged in the nucleus? What is their state of motion? What forces hold them together? How is their energy stored away? Under what conditions can the nucleus be disrupted or this energy released, or the configuration changed? To all of these questions we must confess almost total ignorance.

Think for a moment what this ignorance implies. All of the positive electricity, most of the negative electricity, most of the mass and by far the greater part of the energy of the world reside in atomic nucleuses. We must confess, therefore, that we know as yet very little about most of the world of matter, electricity, and energy. This should make us rather careful about making such statements as one recently published by a leading exponent of the new school of theoretical physicists who wrote, "The underlying physical laws necessary for the mathematical theory of a large part of physics and the whole of chemistry are thus completely known . . . ." It should also warn us against such rash statements as "the breakdown of the law of causality" and "the law of conservation of energy does not apply to individual processes, but only statistically as an average."

A crude analogy will illustrate the relative ad-

vancement of our present state of knowledge of atoms. Liken the nucleus to a building and the extra-nuclear electrons to a group of pebbles resting on the steps of a fire escape on the outside of the building. As we observe these pebbles, we notice that from time to time a pebble falls from one step to another. We do not understand why it falls; hence we make various attempts to hypothecate some model or mechanism that will explain the dropping of these pebbles. Bohr, Sommerfeld, Langmuir all take their turn, but none of them invents a mechanism that satisfies all of the observations. We become discouraged with model building. Finally a brilliant young man, Heisenberg, proposes that we do away with models entirely and concentrate entirely upon the observable quantities—the steps, the pebbles, and their falling. He finds a mathematical expression which accurately correlates the height of the steps (energy levels) with the probability that a pebble will fall (radiate) from one step to another. To the mathematician this accurate formulation of the mathematical relationship between the observable quantities is a complete and satisfactory explanation or theory. The physicist, however, guided perhaps by instinct (which is the accumulated wisdom of the ages) rather than by formal logic, is not satisfied. He feels impressed but a bit confused by the logic of the mathematician, and also a bit distrustful. Down in his heart he feels that there must be something more than a law of probability that makes those pebbles drop. He goes to investigate. He finds the door of the building locked. He pushes; he knocks; he gets help; he rigs up a machine to batter down the door; he makes a small hole through which he sees signs of activity within the building; he builds a bigger and better battering ram; finally he breaks down the door and goes in. Within the building he finds a huge factory; giant cranes carry around great masses of material; enormous machines press, hammer, and draw this material into various shapes. Stupendous forces are at work. The building shakes, and from time to time a little pebble on the fire escape is shaken down from one step to another.

Successful as we have been in describing by equations much of the behavior of those extra-nuclear electrons that move in orbits far outside the nucleuses, we are still grossly ignorant of the most powerful elements of our material world.

So, perhaps, sometime may be resolved the peculiarities and puzzles of our present quantum theory—by small external manifestations of the enormous energy that we know to exist within the nucleus, but about which we now know too little even to make a guess as to how it may influence our present theories.

Be this as it may, where have we left the alchemist? We left him dead, killed by the chemist who had destroyed his hopes of effecting the transmutation of elements. But now the physicist has brought him to life again, with renewed vigor and enthusiasm. For if the atomic nucleus is a structure of electrons and protons, it should be possible to break up this structure or to add to it, and thus to change one chemical element into another. The agencies are no longer earth, water, air, and fire, but electricity and probably electrical particles shot with tremendous speeds into nucleuses.

A most significant event in this story was the discovery of radioactivity by Becquerel 36 years ago. Its significance became evident when Rutherford showed that the alpha and beta particles are, respectively, helium nucleuses and electrons shot out of the nucleuses of radioactive atoms with tremendous speeds, approaching that of light. Its significance became greater when Rutherford further showed that the parent atoms in thus ejecting these particles, transform into atoms of different chemical elements. The law of this transmutation was stated thus by Fajans: Expulsion of a beta particle changes the atom into the next higher one in the periodic table, and the expulsion of an alpha particle changes the atom into one which is 2 steps lower in the table. Here, for the first time, were authenticated cases of transmutation of elements.

The energies liberated in radioactive transformation are prodigious, in comparison with the amount of material involved. For example, radium continually gives off about enough energy to raise its own weight of water from freezing to boiling temperature every hour. By the end of 2,000 years it will be only half used up. By the time it is completely transmuted into its final products helium and lead, any given amount of radium will have generated an amount of heat equal to that from the combustion of 500,000 times its weight of coal. One pound of radium gives off enough energy to heat to boiling more than 13,000 tons of melted ice.

At first it appeared that here at last was in sight the goal of the alchemists. But, alas, there is one difficulty: The process is so slow. Suppose you have a gram of radium (a notable amount); you would have to wait 2,000 years to get half of its energy, another 2,000 years to get half of what is left, and so on. By that time you and your grandchildren long will have ceased to worry about a source of heat. Great as it is, the energy comes off so slowly that it leaks away and cannot be stored for use when wanted. As a practical source of energy it is useless. Alchemists and others have tried every physical and chemical agency that they could devise in an effort artificially to speed up radioactive processes, but without avail.

Today's goal is not gold and silver, but energy. And with the alchemist, who is a practical man trying to get something, is working the physicist, who is not an impractical man, trying to learn something. In fact they are one and the same man.

There are, however, some decided rays of hope, for artificial transmutation has been produced in 3 distinct ways, on a small scale. One of these dates back to about the time of the war, while the others both have been achieved within the past couple of years.

During the war the author was charged with arranging for the demonstration of a French device for locating submarines, for the benefit of British and American scientists engaged in the same problem. One of the British experts was Sir Ernest Rutherford. He sent word by the late Professor Bumstead, however, that he would be delayed through the necessity of completing certain laboratory experiments in which he thought he had split hydrogen nucleuses into 2 parts. "If this is true," he said, "its ultimate importance is far greater than that of the war." With true scientific caution, however, he asked us to keep this matter confidential, since he was not yet sure of his interpretation. This caution was justified, for his subsequent work showed that he had not broken up hydrogen nucleuses; but what he did find was equally significant, for he had succeeded in knocking protons out of the nucleuses of nitrogen, and various other light atoms.

Rutherford's success came not by luck, but by trained physical insight and persistence. Realizing that the possibility of success lay in bringing the largest possible electrical forces to act on the nucleus, he first found that radioactive substance which shot out alpha particles with the highest speed, and then let them shoot at the nucleuses of light atoms like nitrogen and aluminium. He chose these because of the relatively small electric charges of their nucleuses, which repelled the oncoming alpha particles less strongly and therefore permitted them to come closer than the nucleuses of heavy atoms would have done.

Under this vigorous electrical bombardment, some of the nucleuses gave out protons. These were detected by the sparks of light they produced on striking glass plates coated with special fluorescent materials. Their speed and their identification as protons were determined by measuring how far they would shoot through air and how much their paths were curved in a magnetic field. These protons may have been literally knocked out of the nucleuses by the impinging alpha particles, but from some nucleuses, as for example aluminium, the protons were shot out with much greater speeds than they possibly could have acquired from such impacts. It appears, therefore, that the bombarding alpha particle distorts the structure of the nucleus, which settles down into a new state of stability, shooting out the proton in the process. The alpha particle therefore serves as a sort of key to unlock the nucleus and release some of its energy. Ah, here we would seem to have achieved our goal; but no, the process is hopelessly inefficient as a practical source of energy. Only about one alpha particle in 600,000 happens to strike a nucleus in such a way as to produce a transmutation. The other 599,999 simply are scattered without apparently exerting any permanent effect on the nucleuses with which they come into contact.

The process of radioactive transmutation proceeds in its own characteristic slow, sure manner most provokingly unaffected by man's best, but puny efforts.

The second authentic type of transmutation is associated with the discovery of the neutron by Chadwick of Cambridge less than a year ago. For many years physicists have been led by logic to search for this neutron, and they have predicted some of its properties. For example we have atoms of atomic numbers from 92 down to 6, 5, 4, 3, 2, 1—uranium to carbon, boron, beryllium, lithium, helium, hydrogen—whose nucleuses have positive electric charges of 92 down to 6, 5, 4, 3, 2 and 1 units, respectively. Why should there not exist an atom of atomic number 0, with no charge on its nucleus? Such an atom would have no extra-nuclear electrons, and its nucleus would consist of equal numbers of protons and electrons (probably one of each) packed closely together. This atom would have no chemical properties and no physical properties of the usual type, which depend principally upon the electric field of the extra-nuclear electrons. It obviously would be hard to detect, would penetrate easily through even the densest materials, might readily penetrate through even the nucleuses of other atoms. The one thing it could do would be to "bump," for if it happened to strike head-on some other particle, such as a proton or an electron, it could deliver momentum to that particle by impact. If such a neutron particle should exist, not only would it be of the utmost interest as a new "building block" of atomic structure, but also it would be a most interesting tool, for it alone of all known particles could penetrate unopposed the sacred structure of nucleuses and perhaps knock out a key stone or foundation stone of their structure, causing their collapse. But the neutron would be a most unmanageable tool since, having no electric charge, we could not speed it up or control it by an electric field, as we do electrons, protons, and other ions. We would have to take it as we get it and simply watch to see what it does.

Rutherford's achievement in knocking protons out of light atoms was the first success attained in man's long struggle by his own efforts to change one element into another.

Well, Chadwick discovered this neutron and found that it consisted of one electron and one proton. It is like a hydrogen atom whose orbital or valence electron has been completely captured by the proton nucleus—a hydrogen atom shrunk down to almost nothing. For the preceding 4 years Bothe and his German colleagues had been playing with neutrons but did not know it, considering them to be photons, i. e., radiations of wavelength even shorter than the gamma rays of radium. Chadwick showed that, if the law of conservation of energy be true, they cannot be photons, and that their action on other atoms like nitrogen or argon is exactly what would be expected if they be neutral material particles of mass 1, i. e., neutrons. When these neutrons bump into nitrogen, argon, and other atoms, they knock them forward by just the amounts that would be calculated from the laws of impact of balls of mass 1 against balls of mass 14, 40, etc.

This is how the neutron was produced. The Kelly

One striking feature of the transmutation associated with the discovery of the neutron is that the products are heavier atoms than the original atoms. This is a process of atom building, and not atom disintegration as in the previously known cases of transmutation, radioactivity and Rutherford's artificially produced nuclear disintegration. It is highly important to know that atoms may be built up as well as broken down.

Hospital in Baltimore gave Chadwick a lot of old radium emanation tubes that had lost their activity for therapeutic purposes, but which contained the radio active residues. From these tubes Chadwick extracted polonium, an element that ejects alpha particles of extremely high speed. This polonium was spread over a small plate placed about 2 cm away from a plate of beryllium, so that the beryllium was subjected to bombardment by the fast alpha particles from the polonium. It then was found that the beryllium emitted rays of a tremendously penetrating nature, which had the power of ionizing any gas through which they passed and of knocking forward those atomic nucleuses that they happened to hit. All this was studied by means of ionization devices known as Geiger ion counters, or by scintillations produced on fluorescent screens. These rays are the neutrons. Written as a chemical equation, the process is

$$\mathrm{Be}\ (9) + \mathrm{He}\ (4) = \mathrm{C}\ (12) + n\ (1) \quad (1)$$

Similarly boron behaves like beryllium in giving off neutrons according to

$$\mathrm{B}\ (11) + \mathrm{He}\ (4) = \mathrm{N}\ (14) + n\ (1) \quad (2)$$

Here the alpha particle is, of course, a helium nucleus of mass 4, and the products of transmutation are carbon, nitrogen, and neutrons.

The third and last success of the modern alchemists, to date, was the transmutation of lithium when bombarded by swift protons by Cockroft and Walton early in 1932. Here the reaction is

$$\mathrm{Li}\ (7) + \mathrm{H}\ (1) = 2\ \mathrm{He}\ (4) \quad (3)$$

This is peculiarly interesting for several reasons. In the first place it is the first instance of transmutation produced by a particle whose speed had been produced by laboratory methods. In the previous cases the bombarding projectiles were alpha particles whose speeds were fixed beyond man's control by the inherent nature of the radioactive process, except that man could slow them down as desired by interposing absorbing screens in their path. In the present case, however, protons produced by ionization of hydrogen and speeded up by applied voltages up to 600,000 volts were used as the bombarding agents.

In the second place, such a source of bombarding particles may be made ever so much more powerful than the previous sources of alpha particles, for currents of micro-amperes or even milliamperes of protons may be used instead of the tiny natural currents of alpha particles which, from high speed sources like polonium, come out at the rates of only a few thousand or hundred thousand particles per second. Thus we may hope to carry on these transmutation processes on a chemical rather than an atomic scale.

In the third place, the proton has only half the charge of an alpha particle and therefore suffers only half the repulsive force as it approaches an atomic nucleus. For this reason we can hope to shoot protons much farther into nucleuses than alpha particles can penetrate. Protons thus have in a certain measure the advantage of neutrons, which are not repelled at all, and the great advantage of their capability of use at controllable speeds and quantities.

The final interest to the author, personally, in this type of transmutation, is the fact that it was the first of a group of transmutations predicted by Dr. Van de Graaff in a report made to the author about 3 years ago, and on the basis of which he sought further facilities for developing the high voltage generator on which he then was experimenting. He not only predicted the transmutation, but also the resultant energy liberation of 16,000,000 volts. He did not predict how speedy the protons would have to be to effect this transmutation, for there was no basis upon which to calculate it; I think every one was surprised to learn that Cockroft and Walton detected it with proton energies as small as 125,000 volts. At 250,000 volts about one atomic transmutation was found for every thousand million protons that were shot into the lithium. At higher proton velocities the number of transmutations increased. In every case, however, the helium nucleuses produced had about 8,000,000 volts energy apiece, or 16,000,000 for the pair. It was as if the proton, upon entering the lithium nucleus, combined with it to produce 2 helium nucleuses with repulsive forces between them so great that they flew apart with this tremendous 16,000,000-volt energy.

Mass and energy are interconvertible; if mass disappears, energy takes its place in accordance with eq 4. In more familiar terms, $2.13(10)^{13}$ calories of energy are liberated for every gram of matter that vanishes.

How was Van de Graaff able to predict this energy? How, in fact, can all of the energies in atomic transformations be predicted, for they can be predicted in radioactive processes and in the other cases described in eqs 1, 2, and 3? The answer to this question lies in an equation, a product of Einstein's genius and perhaps the most important aspect of his whole theory of relativity. Contrary to the much published statement that only 12 people in the world could understand his theory of relativity, this part of the theory is simple, though perhaps the argument through which the conclusion was reached is more complicated. The equation is, simply

$$E = M c^2 \quad (4)$$

or energy = mass × (velocity of light)^2 or ergs = grams × $9(10)^{20}$.

In more common language, the annihilation of one

pound of matter would create enough energy to heat one hundred million tons of water from freezing to boiling temperatures. Such are the stores of atomic energy. Let us see how this works in reference to the preceding case of transmutation.

A certain isotope of lithium has atomic weight 7.007 and a proton has atomic weight 1.0077; their sum is 8.0157. This splits up into 2 helium nucleuses each of mass 4.00. Thus the product nucleuses have mass 0.0157 less than the original combining nucleuses. This lost mass is converted into energy according to eq 4. To calculate the energy, we first change 0.0157 from chemical units of atomic weight into grams, which gives a loss of $2.83(10)^{-26}$g for every individual transmutation process. According to eq 4 this is equivalent to the liberation of $25.5(10)^{-6}$ ergs. This is the amount of energy that would be acquired by an electron in moving through a potential difference of 16,000,000 volts, which is what we mean by 16,000,000 energy. Thus, by considering various atomic weights in connection with Einstein's equation, we gain a clue as to which atoms may be expected to be relatively easily transmuted, and what the resultant energy will be.

This brings the discussion to its final stage. With these promising beginnings, just recently achieved after centuries of effort, the alchemist takes renewed hope and enthusiasm in his quest. He now has some knowledge of how to plan his attack on the atom. He has at least 2 proved weapons, or rather missiles to hurl at atoms: alpha particles from radioactive sources; and ions that are given tremendous speeds with high voltages (such as protons). He will continue to batter away at the atoms with both of these. Of the 2, the high voltage ion source is the most intriguing on account of the almost unlimited possibilities of high speeds, through the development of high voltage generators, and of high intensities, through the development of potent sources of protons or other types of ion.

It is this feature that gives particular interest to the various new types of high voltage generators that now are being developed in various laboratories. Most promising are those of Lawrence at the University of California, and of Van de Graaff at Princeton University and at the Massachusetts Institute of Technology.

Lawrence does not actually use or develop a very high voltage, but he uses a moderate voltage to give a succession of pushes to the ions until they get to going with speeds that have considerably exceeded 1,000,000 volts, and that may well reach 5,000,000 volts with apparatus under construction. Without going into technical details, the idea may be conveyed by likening the operation to a child in a swing. By properly synchronizing the pushes, the child may be made to swing very high, even though each individual push would lift him only a short distance. Similarly, a voltage of 10,000 volts, applied 100 times in succession to an ion traveling around in a circle under the influence of a magnetic field, will give it the same final energy as if 1,000,000 volts had been applied once.

Van de Graaff has gone back to electrostatic principles and developed a d-c generator in which electricity at low voltage is sprayed onto a rapidly moving insulating belt that carries it up into a spherical terminal upon which it is deposited. The charge and potential of the terminal thus rise up to the point at which further increase is limited by the breakdown of the surrounding insulation. The voltage limitation is therefore that inherently determined by the geometry of the electrodes and the character of the surrounding insulating medium, while the current is limited to the rate at which electric charge is transported by the belts. After successful operation to 80,000 volts of a small generator made of tin cans, sealing wax, and a silk ribbon, a larger generator was built to deliver 30 μamp at 1,500,000 volts. It was successful, as also have been similar and modified generators built during the past year in several laboratories.

The most ambitious of these generators is one designed to deliver 30 or 40 kw at voltages calculated to be 15,000,000 volts and expected to reach at least 10,000,000. This is nearing completion in the Massachusetts Institute of Technology experiment station on the estate of Col. E. H. R. Green at Round Hill, Mass. The terminals are 15-ft polished aluminum spheres, mounted on 30-ft "textolite" insulating cylinders inside of which run the belts that convey the charge to the spheres. Each sphere is a laboratory room, within which the experimenter can assemble and operate the apparatus that bridges the gap between the positively and negatively charged spheres.

Although this Round Hill outfit is quite spectacular, it is probable that the most important developments of this apparatus will be not in the open air but in some container filled with a medium of superior electrical breakdown strength. The voltage increases directly and the power output directly as the square of this breakdown strength. Two such modifications already have been operated successfully in small models, one operating in the best attainable vacuum and the other in gas at about 30 atmospheres pressure.

This completes the story of the "Battle of the Alchemists" to date. They have matched their skill, strength, and all the resources of science against the dogged integrity of the atom for many centuries. Within the last 10 years, but mostly within the last 2 years, it has begun to look as if the atom may succumb all along the battle front, even as it already has surrendered 3 strategic outposts.

Meanwhile Rutherford, Chadwich, Cockroft and Walton, Lawrence, Van de Graaff, Bothe, and many others continue the work. They are the modern alchemists, direct descendants of the alchemists of the middle ages and tracing their ancestry back to Hermes and the fallen angels.

The field is open, and relatively so little explored that we cannot predict what will be discovered. But we should not be surprised if the next generation should uncover the most exciting and far-reaching developments in the whole history of science.

Direct Selection Supervisory Control

In this article is described a new development in supervisory control wherein the apparatus to be operated at a remote point is selected directly, without any intermediate connections to apparatus which is not to be operated. As many as 50 breakers may be controlled over 4 lines, while 25 can be operated over 2 lines.

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MODERN supervisory control systems were designed and placed in permanent operation first approximately 11 years ago; they were of the "code" type and operated over 3 wires. In 1924, the "synchronous" systems were introduced. Recently, a demand for higher speed led to the development of a "direct selection" system which eliminates sequence stepping or counting chains. All systems operate over line wires of telephone size. Modern arrangements use 2 or 4 wires depending on the number of operations to be performed.

In order to obtain an idea of the 3 general principles involved, first imagine a row of small control switches and associated indicating lamps in a dispatcher's office and a corresponding row of power switches or circuit breaker in some remote substation. Regardless of the number of operations to be performed, only 2 or 4 line wires are available first to select the proper switch and then to operate it, meanwhile obtaining a lamp indication of its open or closed position.

Synchronous selecting systems shift both ends of the line wires simultaneously from point to point. Thus, the lines are connected first to No. 1 control switch in the office and No. 1 switch in the substation; then they are disconnected concurrently at both ends and reconnected to No. 2 control switch in the office and No. 2 circuit breaker in the distant substation. This action is repeated until the wires reach the breaker to be operated. Here the stepping action ceases and the line wires are used for direct control. The breaker may be opened or closed at the will of the dispatcher and corresponding lamp signals give him the indication of its position. Thus it may be seen that some time is consumed by connecting the line wires to breakers on which no operation is wanted. Such stepping means usually operate at approximately 10 steps per second so that 5 seconds' time would be required to reach the 50th breaker before any operation could be accomplished.

Code selecting systems operate on a different principle. The plan of selection of one type is first to switch the substation end of the line wire circuits from breaker to breaker until the desired one is reached, by a definite number of impulses sent from the dispatcher's office. The substation equipment then sends an equal number of checking impulses to the office to step that end of the line wire circuits from control switch to control switch until the corresponding one is attained. Again, the breaker may be opened and closed as desired by the dispatcher and at the same time he gets a lamp indication of its status. Here, also, some time is consumed in the selection. In the 2-wire all-relay type, the total selecting time is approximately double that taken by the synchronous system since the check-back takes as long as the selection.

Direct selection systems are practically instantaneous inasmuch as the mode of operation consists of sending a single direct-acting impulse from a control switch at the dispatching office direct to the related circuit breaker at the substation. Instead of switching the line wires by stepping them from point to point, they are connected instantly to the control switch and corresponding circuit breaker by means of circuits which can receive only electric currents having definite combinations of polarities. Each breaker therefore has a definite combination to which it alone responds so that a single impulse of the proper combination immediately selects that particular breaker. No time is required or consumed in connecting the line wires to points where they are not to be used. To insure the accuracy of the selection, however, a checking impulse is returned from the breaker to the dispatcher's office. The time of choosing the breaker and obtaining the verification of its correctness is the same for each breaker.

The control equipment in the dispatcher's office for each circuit breaker is the same as used on practically all previous supervisory systems and consists of:

1 point selection lamp which indicates that the proper point has been selected before operation is attempted.

1 disagreement lamp which indicates an automatic operation in the substation.

1 "trip" supervisory lamp which lights when device is open.

1 "close" supervisory lamp which lights when device is closed.

1 control key whose position determines the operation of "close" or "trip."

1 point selection button which connects the selecting combinations of polarities to the line wires.

There is also common equipment consisting of:

1 operation control button which sends the "close" or "trip" operating impulse to the substation.

1 release button for resetting equipment and stopping an alarm.

Besides the relay equipment and that just listed, the control office is equipped with one 48-volt storage battery, charging facilities, and line wire protectors. The substation equipment consists of corre-

Essentially full text of "Principles of the Direct Selection System of Supervisory Control" (No. 33-31) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933.

sponding relay equipment, interposing relays, one 48-volt storage battery, charging facilities, and line wire protectors.

The direct-selection system is based upon the fundamental method of relay valve operation in which current through the relay in one direction operates it and current s blocked from the relay in the other direction. In the 4-wire classification, the push-button in the dispatcher's office functions to connect battery polarities to the line wires and to operate the register relays at the substation. The receiving relay group consists of 8 unidirectional relay circuits; for these, ordinary neutral relays with copper oxide rectifier valves are employed in order that time-proved devices may be utilized in a manner such that they perform their usual functions.

The 4-wire system is based also upon the employment of individual point selection relays at both ends of the line wires. These relays are particularly useful at the substation to prevent interference between supervisory indications originated at the same instant by the simultaneous tripping of several circuit breakers. Furthermore, they assure the dispatcher that the desired breaker has been selected and connected to the line wires before he attempts operation.

Briefly, an operation is performed by first pressing the point-selection button and waiting until the point-selection lamp glows, indicating that the desired equipment is connected to the line wires ready to be operated; this requires about 0.4 sec. The control key then is turned to the desired operation (in the case of breakers, "close" or "trip") after which pressing the operation control key causes the substation equipment to change position; an indication of the new position then comes to the dispatcher automatically.

To give a more detailed account of this procedure a short outline of the circuit functions is given. In the normal condition of the line circuit both ends are held in readiness for operation over a circuit through the line wires and relays at each end in series. As soon as an operation is initiated from the dispatcher's end or a supervisory indication originated from the substation, this normal circuit is opened in order to disconnect the starting relay at the end which is to act as the receiving end in the succeeding function. By this means interference is prevented effectively when both ends attempt to initiate a selection at the same time.

Assuming that the dispatcher originates the selection, a single impulse is transmitted from the office to the substation after the normal circuit has been opened. A different combination of positive and negative battery potential is applied to the 4 line wires for each of 50 points, thereby energizing the selection relay of the desired point at the substation, through intermediate receiving relays.

When the point selection relay at the substation is energized, it sends a second single impulse back to the dispatcher's office where this impulse causes the operation of the proper point selecting relay. The polarity combination of the return impulse is different from that of the first impulse in order to provide double assurance that the proper relay has been selected at the substation. Simultaneously with the operation of the point selection relay at the office, the associated point selection lamp is caused to glow, thus informing the dispatcher that the selection is completed.

If, for any reason, a point selection relay other than the desired one has been selected at the substation, a polarity combination will be returned to the office which will cause the glowing of a point selection lamp not associated with the originating point. Also, if the correct point selection relay has been operated at the substation, but the return impulse fails to energize the correct point selection relay at the office, the point selection lamp of the originating point will not glow, but that of another point. Therefore, if the dispatcher sees the point selection lamp of the selected point glow, he is assured that the established connection is correct; if he doesn't, he resets and reselects.

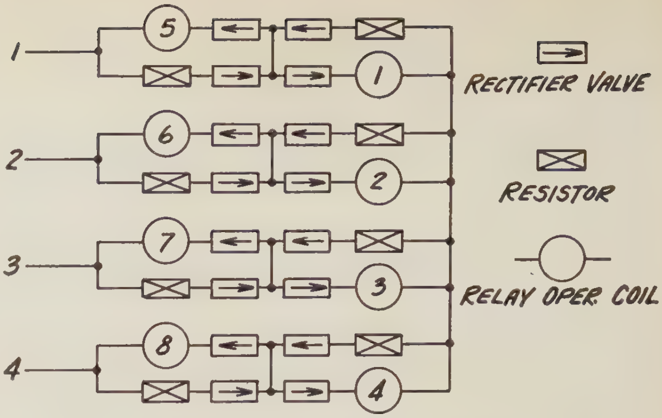

Fig. 1. Schematic diagram of receiving relay circuits for a 4-wire system

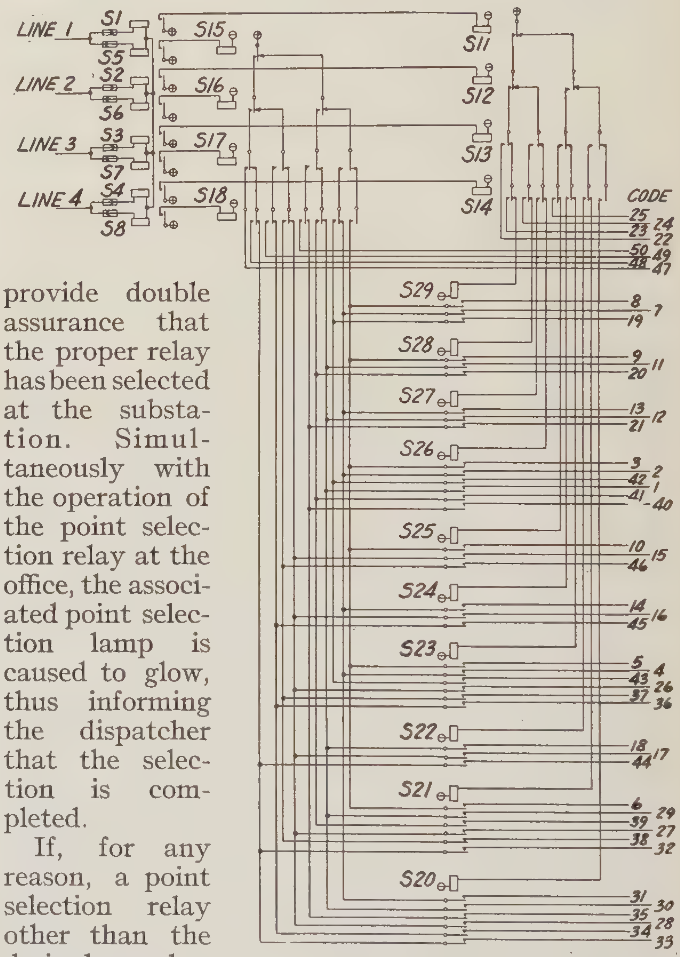

Fig. 2. Register circuit of 4-wire system

The point selection relays remain energized and 2 of the line wires are connected through to the individual point equipment for control and supervision, while the remaining 2 line wires are utilized to maintain the connection until the selection key is restored to its original position. An alarm may be provided to insure the release of the equipment by the dispatcher.

If an automatic operation occurring at the substation is to transmit the corresponding supervisory indication to the office, a single impulse is sent to the office, causing the operation of the corresponding point selection relay. The operation of the office relay sends a checking impulse to the associated point selection relay at the substation. The control and supervisory line wires then are connected through and the supervisory indication transmitted to the office. The connection is maintained until the supervisory lamps at the office actually have changed to agree with the new position of the supervised device, whereupon the connection is released automatically and the circuit returns to its normal rest condition.

Table I—Polarity Combinations

Code	Lines				Relays							
No.	1	2	3	4	1	2	3	4	5	6	7	8
1	+	−			1	...	...	...	...	6	...	...
2	+		−		1	...	...	...	...	...	7	...
3	+			−	1	...	...	...	...	...	...	8
4		+	−		...	2	...	...	...	...	7	...
5		+		−	...	2	...	...	...	...	...	8
6			+	−	...	...	3	...	...	...	...	8
7	+	+	−		1	2	...	...	...	...	7	...
8	+	+		−	1	2	...	...	...	...	...	8
9	+		+	−	1	...	3	...	...	...	...	8
10		+	+	−	...	2	3	...	...	...	...	8
11	+	−	+		1	...	3	...	...	6	...	...
12	+	−		+	1	...	...	4	...	6	...	...
13	+		−	+	1	...	...	4	...	...	7	...
14		+	−	+	...	2	...	4	...	...	7	...
15	−	+	+		...	2	3	...	5	...	...	...
16	−	+		+	...	2	...	4	5	...	...	...
17	−		+	+	...	...	3	4	5	...	...	...
18		−	+	+	...	...	3	4	...	6	...	...
19	+	+	−	−	1	2	...	...	...	...	7	8
20	+	−	+	−	1	...	3	...	...	6	...	8
21	+	−	−	+	1	...	...	4	...	6	7	...
22	+	+	+	−	1	2	3	...	...	...	...	8
23	+	+	−	+	1	2	...	4	...	...	7	...
24	+	−	+	+	1	...	3	4	...	6	...	...
25	−	+	+	+	...	2	3	4	5	...	...	...
26	−	+			...	2	...	...	5	...	...	...
27	−		+		...	...	3	...	5	...	...	...
28	−			+	...	...	...	4	5	...	...	...
29		−	+		...	...	3	...	...	6	...	...
30		−		+	...	...	...	4	...	6	...	...
31			−	+	...	...	...	4	...	...	7	...
32	−	−	+		...	...	3	...	5	6	...	...
33	−	−		+	...	...	...	4	5	6	...	...
34	−		−	+	...	...	...	4	5	...	7	...
35		−	−	+	...	...	...	4	...	6	7	...
36	−	+	−		...	2	...	...	5	...	7	...
37	−	+		−	...	2	...	...	5	...	...	8
38	−		+	−	...	...	3	...	5	...	...	8
39		−	+	−	...	...	3	...	...	6	...	8
40	+	−	−		1	...	...	...	...	6	7	...
41	+	−		−	1	...	...	...	...	6	...	8
42	+		−	−	1	...	...	...	...	...	7	8
43		+	−	−	...	2	...	...	...	...	7	8
44	−	−	+	+	...	...	3	4	5	6	...	...
45	−	+	−	+	...	2	...	4	5	...	7	...
46	−	+	+	−	...	2	3	...	5	...	...	8
47	−	−	−	+	...	...	...	4	5	6	7	...
48	−	−	+	−	...	...	3	...	5	6	...	8
49	−	+	−	−	...	2	...	...	5	...	7	8
50	+	−	−	−	1	...	...	...	...	6	7	8

Relays 1, 2, 3, and 4 operate when *positive* polarity is applied to lines 1, 2, 3, and 4, respectively; relays 5, 6, 7, and 8 operate when *negative* polarity is applied to lines 1, 2, 3, and 4, respectively.

Means are provided at the substation for effecting a proper succession of supervisory signals, if 2 or more supervised devices at the substation change their positions at the same time. This guarding arrangement is effective even if several devices change their positions at exactly the same instant. This is accomplished by interlocked relay circuits in which only one relay may be operated at a time.

Brief intervals are introduced between the normal rest condition and the first impulse, between this first impulse and the return impulse and between the return impulse and the completion of the control and supervisory connections, during which intervals the line wires are disconnected entirely at both ends. The purpose of these intervals is to give each end sufficient time for the preparation of the next succeeding function.

Potential from the 48-volt battery is applied to the 4 line wires according to the 50 polarity combinations shown in Table I. Code No. 1 calls for positive potential on line 1 and negative potential on line 2 with lines 3 and 4 remaining open (not used); relays 1 and 6 respond as may be seen from Fig. 1. Again code No. 50 calls for positive potential on line 1 and negative potential on lines 2, 3, and 4; relays 1, 6, 7, and 8 respond. Thus each selection puts some code of polarities on the line wires; hence the name "Polaricode" has been applied. Two line wires only are used for 12 of the 50 codes; 3 only are used for 24 codes, while all 4 are used on the remaining 14 codes.

A diagram of the receiving relays with their associated register circuit is shown in Fig. 2. As already mentioned, the selection of No. 1 breaker calls for the energizing of relays 1 and 6; at the substation end, these are known as S1 and S6. When the contacts of S1 and S6 are closed, relays S11 and S16 are energized. Relay S11 in turn energizes relay S26 over "break" contacts of relays S12, S13, and S14. This completes the selection circuit for register relay No. 1 from battery positive through "break" contacts of S15, "make" contacts of S16, "break" contacts of S17 and S18, "make" contact of S26, and No. 1 relay coil to negative battery. The other register relays are energized by similar apparatus circuits. Thus any one of 50 breakers can be selected by a single impulse over 4 line wires. The time for any one of the 50 selections, including check-back, is about 0.4 sec.

The 2-wire direct selection system utilizes pulsating battery voltage in addition to the direct voltage as utilized in the 4-wire arrangement. If direct voltage alone were used, only 2 selections would be possible over 2 wires; the addition of the pulsating voltage provides for 3 more selections or a total of 5. Thus on 2 wires the instantaneous selection of any one of 5 points is possible.

Referring to Fig. 3, the vibrating relay for producing the pulsating direct current is shown as relay V. Just to the right is the push-button arrangement for applying the 5 different potential combinations to the line wires. On the extreme right are the receiving relays in the substation. The contacts of the receiving relays determine which register relay responds.

The fundamental action in the 2-wire polarized selection is as follows: Suppose both contacts of pushbutton 1 are closed. Positive battery is applied to the upper line wire and negative to the lower; relay P is energized. Relay N is not affected because of the rectifier valve in series with its operating coil; relay A is not affected because of the condenser. However, if the 2 contacts of pushbutton 2 are closed, the polarities of the line wires are reversed and relay N responds while relays P and A are unaffected.

Thus, when pushbutton 1 is closed, the circuit may be traced from positive battery, through "make" contacts of relay P, "break" contacts of relay N, "break" contacts of relay A, and the operating coil of relay 1 to battery negative. Thus relay 1 is energized almost instantly after pushbutton 1 is operated. A similar circuit may be traced to energize relay 2 when pushbutton 2 is operated.

When any one of pushbuttons 3, 4, or 5 is pressed, the vibrating pole changer is started, producing pulsating voltage on the secondary of the transformer. This circuit may be traced from positive battery through the contacts of pushbuttons 3, 4, or 5, through 2 parallel paths to battery negative. The first of these paths goes through the "break" contacts of the vibrator V, through the operating coil of V to battery negative; the second path goes through another pair of "break" contacts of vibrator V, through half of the primary winding (in the up direction) of the transformer through resistor R to battery negative. Through the first path coil V is energized; this changes the position of its 3 sets of contacts so that a circuit is completed from battery positive through pushbuttons 3, 4, or 5, through "make" contacts on V, and through the other half of the transformer primary winding (in the down direction) and resistor R to battery negative.

Thus, when the operating coil V is deenergized, a half wave is produced on the transformer secondary in one direction and the energized position of V produces the other half wave in the opposite direction. The 3 combinations obtained from this source are full wave pulsating currents, positive pulsating (positive half wave), and negative pulsating (negative half wave), the latter 2 being obtained by rectifier P.

If pushbutton 3 is pressed, the positive half wave is impressed on the line wires. The circuit may be traced from the lower end of the transformer secondary winding, through resistor R_1, through rectifier P, through pushbutton contact 3, over line wire 1, through the relay circuits of P and A in parallel, over line wire 2, through another contact of pushbutton 3, to the other end of the secondary winding of the transformer. The substation selection circuit may be traced from battery positive, through "make" contacts of relay P, through "break" contacts of relay N, through "make" contacts of relay A, through the operating coil of relay 3 to battery negative. Therefore, when pushbutton 3 is operated in the dispatching office, relay 3 in the substation responds instantly.

The action of pushbutton 4 is similar to that of 3, except that the negative half wave is used. Relays N and A respond, which produces a register circuit such that relay 4 responds instantly. When pushbutton 5 is pressed, both half waves are impressed on the line wires so that the 3 relays P, N, and A respond and relay 5 is energized.

Since only 5 selections are available on 2 wires without going to other apparatus to obtain various voltage or frequencies, the simple way of expanding control is to send more than one selecting combination. With 2 combinations, any one of 25 can be selected.

Referring to Fig. 4, the first selecting impulse chooses one of the 5 paths labeled A, B, C, D, and E. Thus the circuit is completed from positive battery to one of the 5 groups. After this selection is checked back to the office, the second selecting impulse completes the circuit to the desired relay by energizing one of the relays in the group. If relay No. 17 is to be selected, the first selection would be the fourth code closing contact D and the second impulse would be the second code closing contacts b. One operation only is required by the dispatcher for selecting any one of the 25 relays.

In conclusion, the systems described are designed so that they may accommodate all of the auxiliaries used with other previously used assemblies. These include telemetering of various forms, remote synchronizing, and position control. The "anti-pumping" feature likewise is preserved.

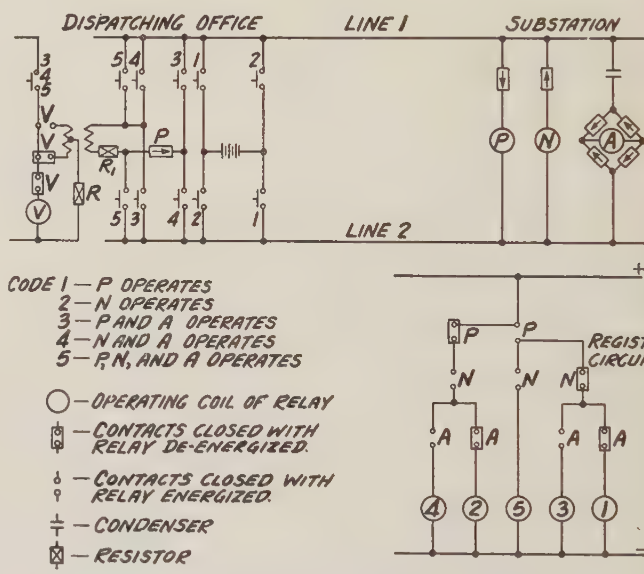

Fig. 3. Schematic diagram of 2-wire system

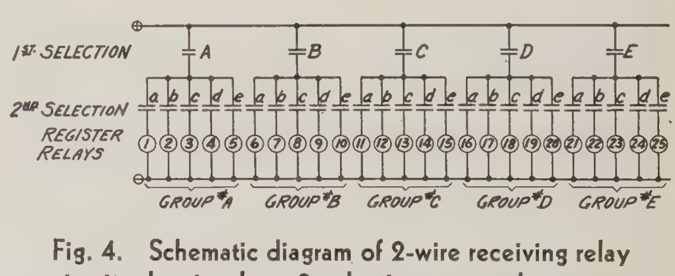

Fig. 4. Schematic diagram of 2-wire receiving relay circuits showing how 2 selections expand a system from 5 possible operations to 25

Air Conditioning of Passenger Cars

Many interesting design problems were encountered in the development of a suitable air conditioning equipment for railway passenger cars. In this article is presented a discussion of these problems together with a description of their solution, thus providing an account of a most interesting development as well as an outline of the requirements for this service.

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CONDITIONING of the air in railway passenger cars during the summer months not only is desirable, but experience obtained during the summer of 1932 has proved that the air conditioning equipment developed will operate satisfactorily and meet the space and weight limitations of railway service.

The advent of summer air conditioning to railway cars has introduced engineering problems of the most severe kind. One set of solutions of this problem, a problem which is of outstanding interest to the traveling public, is outlined in this article. While air conditioning for commercial purposes is not new, the equipment is not applicable to railroad service. To obtain a suitable equipment involved the development of new systems of power supply, more compact and lighter refrigerating plants, and brought out many problems in mounting and in design for limited space, incidental only to railway application.

The ideal equipment for railway service in addition to being light in weight, reliable, and mechanically suited to this application, should also be easy to install, inspect, and maintain. It should require no floor space, no attention of any kind between regular inspection periods, and all unnecessary auxiliary apparatus should be eliminated. Lastly, both the power supply and cooling systems must have ample capacity, and the system must be suitable for operation either in transit or in terminals.

Due to limitations in available power capacity and space, it is impractical to do all the things on a railroad car which can be done more simply in commercial applications. However, experience has proved that comfortable conditions on a railroad car can be provided which, in general, approach the best industrial and domestic practice.

The refrigerating capacity is used both to reduce the air temperature and to take moisture from the air. For comfort, holding the moisture content down is as essential as lowering the temperature. Experience has shown that the maximum temperature differential between inside and outside conditions should not exceed 15 deg F, except under extreme conditions. The temperature differentials recommended by the American Society of Heating and Ventilating Engineers should be followed. For outside temperatures above 95 deg F, the inside of the car will be sufficiently comfortable if the maximum temperature is held to 82 deg F and the relative humidity to 60 per cent.

Capacity of Equipment

The capacity of the refrigerating plant required to cool a car properly depends upon many factors, including the number of passengers, size of car, type of insulation, and type of windows. Therefore, to meet the requirements of every type of car exactly would require a wide variety in compressor capacities, a procedure which is not economical from the manufacturing standpoint.

Calculations have been made for a large number of different types of cars. These calculations are now supplemented by test experience on coaches, diners, parlor cars, and sleeping cars. These data indicate that a system which will deliver 6 tons of refrigerant at the cooling coils will be satisfactory for the average car installation; this system requires a total of approximately 12 hp motor capacity.

In addition to the cooling load, the source of power must provide for car lighting and battery charging. Fortunately the cooling system usually is operated only intermittently when the lights are used, so that these loads do not pyramid. It is essential though that the source of power have ample capacity to maintain the batteries under the most severe operating schedules. To provide for these loads properly, a total of 15 kw in power capacity is required on each car.

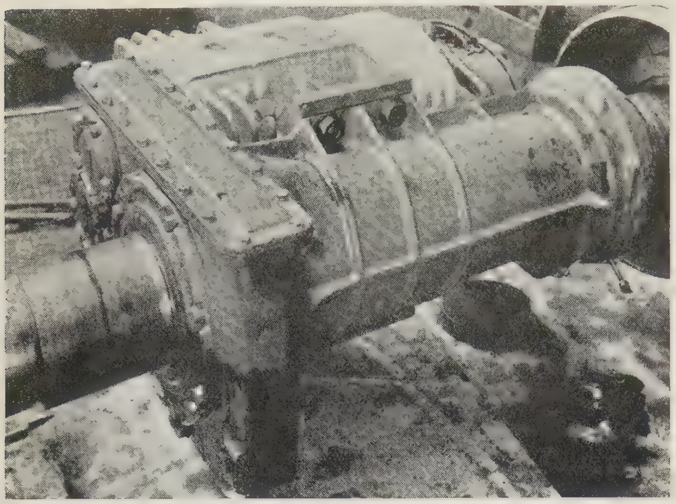
Due to the operating advantages derived by having each car an independent unit suitable for operation any place at any time, present development has followed along the lines of using an axle generator on each car, augmented by a battery for power during station stops. This practice required the development of a light weight generator of large capacity, and a light weight battery of 800–1000 amp-hr capacity.

Generator Drive

For generators of 15-kw capacity a new type of drive was essential. Present flat belt drives are limited to about 5 kw maximum. To obtain light weight generators which will fit into the available space, high speeds are required, involving belt

Essentially full text of "Application of Air Conditioning to Railroad Passenger Cars" (No. 33M1) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933.

speeds far in excess of present practice. The low center sills of passenger cars limited the size of pulleys. This in turn made large speed increases with belts alone prohibitive. The belts are further subjected to severe shocks, such as occur when coupling cars, and also are exposed to the weather. They must also accommodate the relative movement of



the trucks, axles, etc. The drive problem may be solved in 2 ways, either by a gear drive or by a new form of belt drive. From the standpoint of the drive alone, gear drives undoubtedly offer the better solution.

The principal objection raised by the railroad operators to the successful application of a gear drive is the stress which would be imposed on the gear teeth when coupling cars. No experience was available in similar service. As a result 3 types of gears have been placed in service; namely, solid gears, flexible gears, and slip gears. All have worked excellently and no failures of any kind have occurred with any of the gears. Consequently, for bumping stresses, it has been proved definitely that any of these gears are satisfactory.

Another problem involved in a gear drive is the elimination of noise. This has been solved by designing an oil tight totally enclosed gear case, by using roller bearings to maintain accurate gear centers, and by using helical gears with several teeth always in mesh.

Due to the low center sills on some cars, a drive for universal application was limited to a 15-in. diam gear. This did not allow sufficient gear center distance to accommodate a 15-kw generator with the gear ratio required. To give a greater gear center distance, an idler gear with roller bearings was interposed between the main gear and the generator pinion.

There is considerable difference of opinion relative to the question of retaining a standard axle. Its retention would necessitate some form of split gear, which past experience on street cars and locomotives has shown at high pitch line speeds to be unsatisfactory. The elimination of the gear drive for standard axles practically forces a modified belt drive.

To obtain long belt life the belts should operate at low speeds and always in as perfect alinement as possible. The low belt speed can be obtained by building into the generator itself a small reducing gear unit to obtain the necessary generator speeds. By mounting the generator on the end frame of the truck, the best belt alinement was obtained. A tension device accommodates the belt stress, and the generator is driven from the pulley on the tension device by a torque shaft and universal joints.

Twelve generators with gear drives have operated throughout the past summer with most gratifying

Fig. 1. (Left) Fifteen-kw axle generator and gear drive

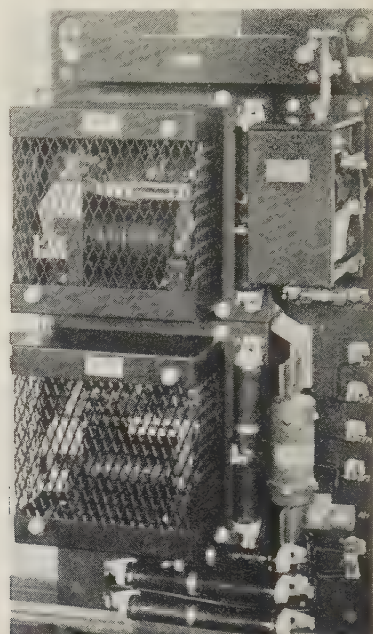


Fig. 2. (Right) Generator regulator

results. Belt drive units have shown excellent results in factory tests.

Generator

The development of a 15-kw generator which would fit into the space available on standard 6 wheel trucks offered many problems. These trucks have longitudinal members inside the wheels which limit the total space to about 37 in. Similarly, the distance from the center of the axle to the end frame is only 23 in. This space had to accommodate both the generator and the drive. Of the 37 in., 3 in. were required for axle lateral play, giving only 34 in. for the generator and drive.

Steam railroad passenger cars operate in all sections of the country, including the deserts of the west and the heavy snow regions of the north. For such service, a totally enclosed machine was desirable; this made still more difficult the problem of securing sufficient rating in the given space. These generators also must deliver their rating at train speeds of from 25 to 90 mph. The center sill and rail clearances limited the overall diam to 18 in.

High peripheral speeds were used to obtain a greater rating. At 90 mph the generator speed is 3,200 rpm. This required the best quality of core bending and commutator construction. The frame was cast with ventilating fins in all available spaces to take advantage of the movement of air over the frame on a moving train. Class *B* insulation was used throughout. Special types of armature coil and core were developed to allow the use of the maximum amount of copper in the available space.

After obtaining the necessary rating, serious problems still presented themselves. As these generators charge the storage batteries, their polarity must always be in the same direction irrespective of train direction. Second, constant voltage had to be maintained over a wide range of speeds. In addition, the characteristics of the generator and its control must be so designed that they give the maximum battery life.

The problem of maintaining polarity offered many difficulties. Since the standard car lighting circuits use 32 volts direct current, the current rating of the generator is approximately 400 amp. Because of these heavy loads, rotation of the brush rigging by brush friction is not a positive operation. The use of polarized relays in traction service has never been successful.

Along with the problem of polarity was the problem of voltage regulation. The field currents with a large generator exceeded those which could be handled successfully with a sensitive vibrating regulator. The solution of both of these problems was obtained by the use of a small exciter placed on the end of the generator shaft. The frame of this exciter was made of special, high retentivity iron and magnetically insulated from the generator. The field circuits of the exciter, excited by the generator, then always remained in the same direction. With a reversal in train direction, the exciter reversed the generator field, but since the generator armature also reversed, its polarity remained unchanged. By regulating the exciter fields, the regulator was required to handle only very small currents.

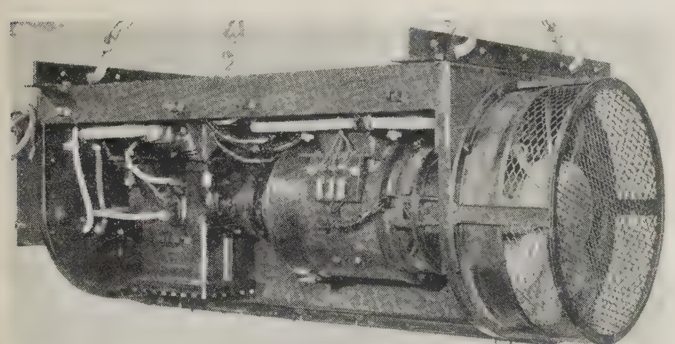


Fig. 3. Six-ton refrigerating unit with covers removed

The regulation of a generator of this type deserves special mention. When the generator voltage reaches that of the battery, the generator must be connected in to carry the load. The voltage then increases to about 38 volts to charge the battery, and this voltage is maintained at all higher speeds. This can be accomplished either by inserting resistance in the exciter field or by manipulation of the field circuits. The latter is preferable since it eliminates carbon pile resistors. The scheme developed in this instance has given excellent results. The exciter has 4 field windings, 2 main and 2 auxiliary. At low speeds where maximum excitation is required, all fields are in series. The regulator then cuts out $^1/_2$ the main field as the train speed increases. At still higher speeds the auxiliary winding opposes the remaining main field winding. The combined result of regulation and changing connections gives very good voltage characteristics.

The third problem is that of battery charging. To obtain the characteristics, a tapered charge should be delivered to the battery. This is accomplished by the use of a modified constant potential system. In addition, a series coil has been added to the regulator to prevent overloads with a completely discharged battery.

Refrigerating Apparatus

Because of the limitations of railway service, the refrigerating system should eliminate the necessity for constantly replenishing the water and also should provide the most efficient refrigerating cycle. The first involved some means of condensing the refrigerant with air. The second involved direct expansion of the refrigerant in the coils where the car air was cooled. The refrigerant used was Freon (dichlorodifluoromethane). This gas can be condensed with air at pressures of 150 to 180 lb gage, and can be successfully operated at 30 to 40 lb gage pressure on the suction side.

The space and clearance limitations on a railroad car are very severe. The clearance limits in districts where third rails are used, are more severe than in other sections of the country. These limitations required the minimum size of refrigerating box. For ease of installation and maintenance, a complete condensing unit in one unit, factory assembled, is desirable. As it costs money to haul

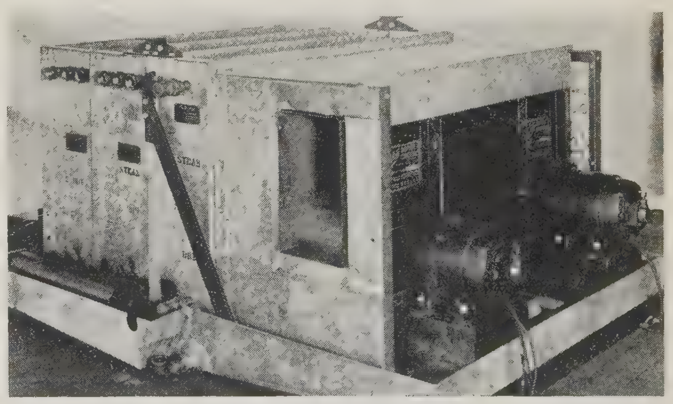


Fig. 4. Cooling unit

around excess weight, it was considered desirable to reduce the weight to a minimum. From the maintenance standpoint, a direct driven compressor offers the best form of drive.

To meet these requirements a high speed compressor was developed to operate with Freon and sufficiently small to meet the space and clearance limitations. The principal difficulty in a high speed compressor was the development of a valve which would operate at these speeds with Freon and at the same time provide a volumetric efficiency with a high speed compressor equal to that of the slower speed units. Sufficiently large port openings must be provided. The dead space above the piston on the compression stroke had to be reduced to a minimum. The problem of lubrication had to be settled and a valve was required which would not get noisy with wear.

Considerable experience had been obtained in domestic refrigerator compressors which led to the development of a valve consisting entirely of flat strips of special grade steel. The steel strips are subjected only to deflection of a small amount and therefore no lubrication is required and all possibility of noise with wear is minimized. Exhaustive fatigue tests have been made on this type of valve, and show that it will have a very long life.

For bearing and cylinder lubrication with the high speed, a geared oil pump was located in the crank case to provide forced lubrication throughout. The third difficult problem is a satisfactory seal for the refrigerant on the crankshaft. Any refrigerating gas is extremely hard to hold, and Freon is especially difficult. A special sylphon bellows seal was developed, in which a special alloy seal was made against a steel disk, and held tight by spring pressure. The construction was such that the gas pressure in the crankcase increased the pressure on the seal.

The proper speed was a compromise between compressor construction and motor speed. After careful consideration of all factors, a speed of 1,000 to 1,200 rpm appeared most desirable.

To eliminate the use of water, an air cooled condenser is necessary. Operation at high ambient temperatures without excessive pressures requires a large cooling surface in the condenser and a large volume of air. A condenser was obtained which would fit into the rear of the unit and require no more length or depth than that required by the other apparatus. A large amount of research work was devoted to a fan capable of delivering about 6,000 cu ft per min with minimum horsepower requirements. A special design of propeller type fan made of aluminum alloy was developed which required about 1.5 hp for this quantity of air. This fan had to be sufficiently small to meet the railroad clearances which considerably hampered the design.

One of the big problems in mechanical cooling of cars is that of pre-cooling. Often sleeping cars are parked for occupancy for several hours. A battery of sufficient size to take care of this service is prohibitive. During the periods when the train is moving, a 32 volt d-c drive is used since practically all cars are now equipped with this system. However, pre-cooling cars throughout a terminal with 32 volts would require a prohibitive distribution system. At most locations the central stations can provide 220–440 volt, 3 phase, 60 cycle power very easily, so this is the logical system to use.

An a-c, d-c drive within the limited space required the design of a new motor. Because of the fact that the equipment operated in all parts of the country, an enclosed d-c motor was considered desirable. By special insulation, ventilating fins, and special coils, a combination of a d-c motor and an a-c motor with common shaft was produced within the space requirements of an ordinary d-c motor of the same capacity. To provide 6 tons of refrigeration and to cool the condenser, approximately 11 hp is required. When operating from the a-c source the d-c motor acts as a generator to charge the storage batteries when such charging is required. To accomplish this added feature the a-c motor has a continuous rating of 15 hp.

Car Ventilation

Experience has shown that with a duct distribution system the maximum amount of air which can be supplied to a car without objectionable drafts is about 2,500 cu ft. To handle this amount of air a total duct cross-section of at least 200 sq in. is required.

The duct system unquestionably provides the best method of distribution in a car. However, the installation of ducts in existing cars adds to the expense, and for that reason is not desirable if it can be avoided. Considerable work has been done with systems other than ducts, and on certain cars this form of distribution unquestionably will be used.

To provide for the health of the passengers, approximately 25 to 30 per cent of the air circulated in the car should be fresh air. This air is brought into the car through openings in either the deck or the vestibule, and passes through some form of filter. It is mixed with the recirculated air before being cooled.

The cooling units used with all systems are essentially the same. Either brine, water, or refrigerant is carried through the coils over which the air is passed to cool it before entering the car. With systems using a refrigerant, it is expanded from a liquid at high pressure to a gas at low pressure, during which heat is absorbed from the air. With a duct system of ventilation fan motor capacity of about one hp is required to handle sufficient air.

Conclusions

Experiences obtained during the summer of 1932 indicate the following:

1. Conditioning of the air in railway passenger cars is desirable, feasible, and practical.

2. Complete systems from the source of power supply to the conditioned air have been worked out to the point of practicability.

3. Performance comparable to the best stationary practice is now available for cars.

4. Equipment to accomplish the above can be constructed within the space and weight limitations of railway service.

Flashover Tests on 26-Kv Wood Pole Structures

Results of a series of impulse and dynamic flashover tests on unit pole transmission construction now in standard use on a large 26-kv electric power transmission system are presented herewith. From the data obtained the net flashover voltages of wood and porcelain combinations of simple pole tops can be estimated. With the aid of data now available it is possible to design a wood pole line having almost any practical degree of lightning reliability.

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TO SECURE adequate data from may be determined the relative lightning performances of wood pole structures for electric power transmission lines, a series of laboratory tests has been made on the 26-kv wood pole construction now in use by the Public Service (N. J.) Electric and Gas Company, in cooperation with the Westinghouse Electric and Manufacturing Company. In these tests flashover data were obtained for component parts of wood pole structures; this information should facilitate coordination of insulation between poles on similar lines, aid in applying protective gaps, and furnish a guide to the comparative impulse strengths of both present and new types of construction. An analysis of factors governing the development of a power arc following impulse flashover shows that, within the usual physical limits, the reliance upon air or wood separations to prevent lightning outages will be unsatisfactory. The application of various protective measures is discussed. Tests were made by subjecting actual unit pole assemblies to impulse and 60-cycle voltages, separately and simultaneously. Test equipment consisted of a million-volt surge generator (see "Lightning Laboratory of Stillwater, New Jersey, by R. N. Conwell and C. L. Fortescue, A.I.E.E Trans., v. 49, 1930, p. 872) and a 60-cycle, 750-kv test set. For all impulse tests a 0.5–0.75 × 60-μsec positive wave was used. No corrections were made for barometric pressure or humidity.

In plotting volt-time curves (see "Ionization Currents and the Breakdown of Insulation," by J. J. Torok and F. D. Fielder, A.I.E.E. Trans., v. 49, 1930, p. 352) of combinations involving wood, the a-c flashover voltages sometimes exceeded the impulse values. This irregularity is ascribed to the variation in wood specimens, the difference in path of the impulse arc at long and short time flashovers, and to the difference in path of the impulse and dynamic flashovers. However, as the 60-cycle datum point is taken on the steep front of the wave, a large variation in this value will change the impulse curve but slightly.

In applying the volt-time curves given in this paper, the regions below 1 μsec should be considered approximate since the measuring circuit may have distorted the wave front slightly and the a-c flashover values may be erratic.

Tests on Component Parts of Pole Tops

In these tests it was desired to obtain some simple basic means of comparing pole top flashover values. Unfortunately preliminary tests showed that when wood is involved, no workable relationship exists between impulse and a-c values. Accordingly, impulse tests were made on the component parts of pole top assemblies so that the data secured could be used to compare other pole tops.

A series of 60-cycle flashover tests was made on wooden crossarms and on each component assembly. In Fig. 1 are shown the range of values for dry seasoned arms, for unseasoned arms, and for wet arms. The results on crossarms in combination with porcelain are given with the impulse curves.

Results of these 60-cycle crossarm test results may be summarized as follows:

1. Both unseasoned and wet wood have negligible a-c insulation strength.

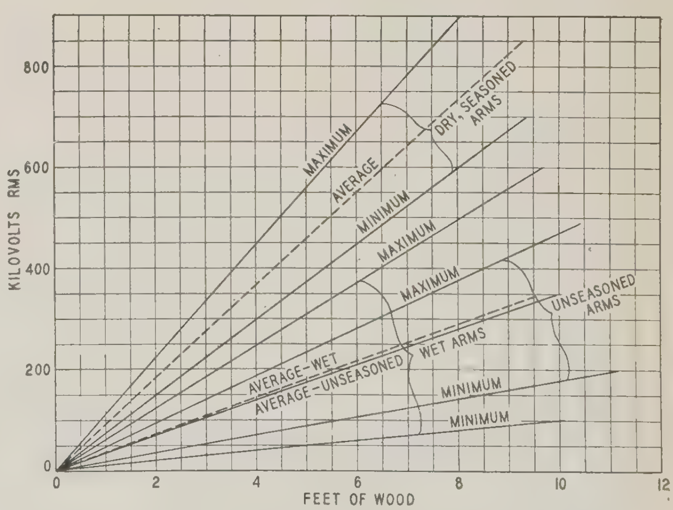

Fig. 1. 60-cycle flashover data for dry, wet, and unseasoned fir crossarms

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Full text of "Impulse and Dynamic Flashover Studies of 26-Kv Wood Pole Transmission Construction" (No. 33-44) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933.

* Formerly with the Westinghouse Elec. and Mfg. Co., East Pittsburgh, Pa.

2. Creosoting does not alter appreciably the 60-cycle insulation of wood.

3. The 60-cycle values vary so greatly for different specimens and conditions that they give no indication of the impulse strength.

In securing volt-time impulse curves, one terminal of the test circuit was grounded. This method gives actual impulse flashover voltages when the arc is from any conductor to a ground, but these values indicate only comparative impulse strengths for flashover between conductors. For the latter case, it would be necessary to consider, among other factors, the induced voltage on the second conductor.

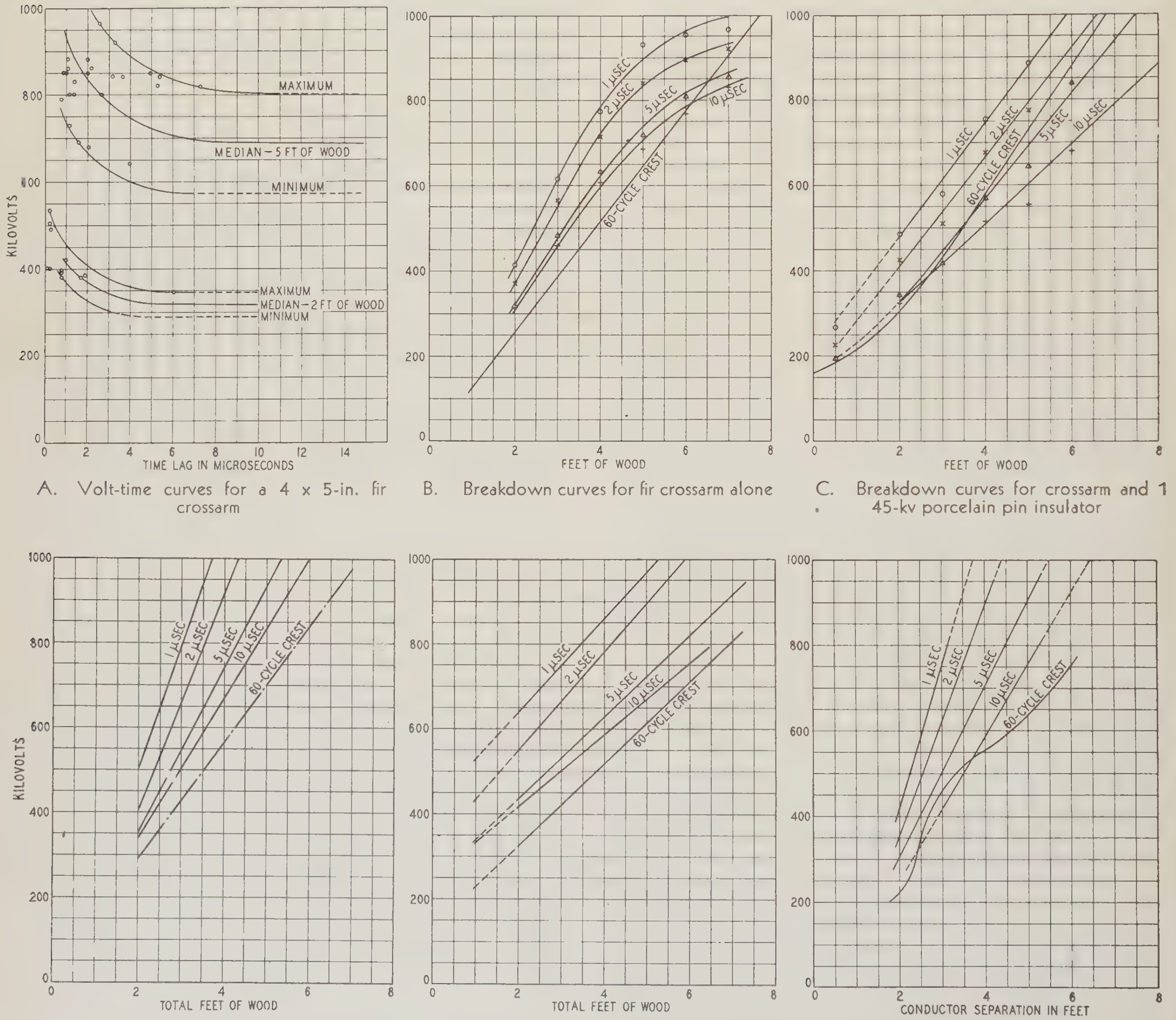
No data are given here for sparkovers in midspan, as adequate information on air breakdown already is available. Results of impulse tests on pole top component parts are summarized in the following paragraphs:

1. Various lengths of fir crossarm.

Crossarms used were standard creosoted fir arms of 4 x 5-in. cross-section which had been used for several years. The electrodes consisted of two metal bands around the crossarm. Typical volt-time curves and breakdown curves for different time lags are shown in Fig. 2, A and B. A wide scattering of points may be noted, the extreme points in the volt-time band being nearly 20 per cent from the median curve. These erratic results are explained by the non-homogeneity of the wood, and by variation in physical characteristics of the different specimens tested, such as moisture, aging, and type of grain. Considerable variance was found in tests on a single arm with all external conditions constant. Investigation of the comparative impulse strengths of wet and dry, freshly creosoted and untreated, new and well seasoned, and of splintered and unscarred arms failed to reveal any measurable trend from these causes.

2. Pole tests.

Some tests made on a section of wood pole alone between electrodes of wire banding showed such a wide variance between individual poles that the tests were not extended, particularly since data on similar tests already are available. (See "Impulse Insulation Characteristics of Wood Pole Lines," by H. L. Melvin, A.I.E.E. Trans.,



A. Volt-time curves for a 4 x 5-in. fir crossarm

B. Breakdown curves for fir crossarm alone

C. Breakdown curves for crossarm and 1 45-kv porcelain pin insulator

D. Breakdown curves for 2 insulators mounted on the same arm, insulator spacing varied

E. Breakdown curves for 2 insulators mounted on a 10-ft arm, with various brace lengths (See Fig. 3)

F. Breakdown curves for 2 insulators each mounted on a separate arm, the arms being separated vertically

Fig. 2. Typical volt-time curves for a fir crossarm (A) and breakdown curves (B to F) for component parts of wood pole top assemblies

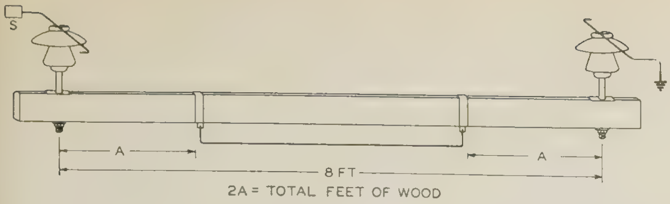


Fig. 3. Test arrangements for 2 45-kv pin insulators mounted on a 10-ft fir crossarm with portion of arm "short circuited" to simulate crossarm braces of various lengths (See Fig. 2E)

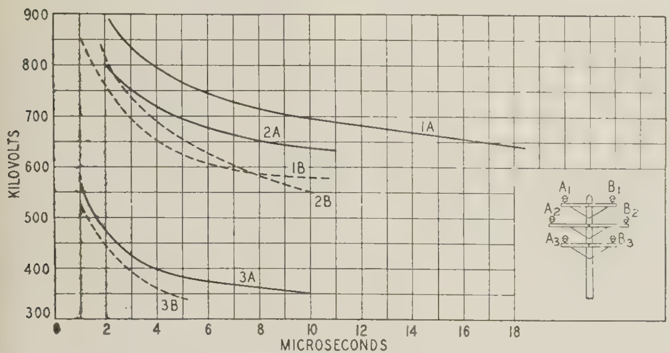


Fig. 4. Comparison between actual (solid line) and estimated (dashed line) flashover curves for vertical configuration pole with double arms and metal braces

1A and 1B. Flashover from A_2 to B_2
2A and 2B. Flashover from A_2 to A_3
3A and 3B. Flashover from A_3 to B_3

v. 49, 1930, p. 21; and "Surge Characteristics of Insulators and Gaps," by J. J. Torok, A.I.E.E. Trans., v. 49, 1930, p. 866.) Impulse tests on a badly checked and weathered chestnut pole showed a sparkover voltage of about 90 kv per ft at 5 μsec. The impulse spark occurred within the wood fibers and oscillograms showed a slow voltage drop at breakdown, similar to a discharge through a high resistance.

3. Sparkover from conductor to ground over arm. Breakdown curves for different time lags are shown in Fig. 2C. The impulse voltage was applied to an 8-ft rod mounted on an insulator. A grounded band around the arm at various distances from the center line of the insulator formed the other electrode. The volt-time curves show scattering similar to the crossarm tests. The insulator used on all tests was a standard 45-kv pin type.

4. Sparkover between conductors on same arm. Breakdown curves are shown in Fig. 2D for sparkover between conductors mounted on insulators at varying spacings on the same arm. Because of the air breakdown, the original data points show but slight scattering.

5. Sparkover between conductors spaced 8 ft on a crossarm with part of arm short circuited. This test was made to simulate metal braces of varying lengths. The test arrangement is shown in Fig. 3 while Fig. 2E gives the breakdown curves.

6. Sparkover between wires separated vertically. Sparkover voltages between conductors on insulators mounted on crossarms, one vertically above the other, were measured for varying spacings. Breakdown curves are shown in Fig. 2F.

Comparison of impulse strength calculated from these component-part curves with that of actual pole tops shows a maximum deviation of 20 per cent and an average of about 10 per cent. Actual conditions on a pole may vary considerably from test conditions, due to gradient distortion by adjacent metal. A comparison of the measured sparkover voltages on a double armed pole with those estimated from the component part curves is given in Fig. 4. Since the sparkover voltages for double arms are about 7 per cent higher than for single arms, the agreement, in general, will be closer than indicated.

Table I—Dimensions of Standard 26-Kv Pole Top Assemblies Tested (See Figs. 4 and 5)

Configuration	Crossarms	Crossarm Vertical Spacing	Braces	Conductor Spacing, In. A_1–B_1	A_2–B_2	A_3–B_3
Double-circuit, triangular	One 7 ft One 10 ft	32 in.	Metal, 60-in. Spread, 18-in. Drop	76	112	40
Double-circuit, vertical	Two 7 ft One 10 ft	42 in.	Same	76	112	76
Single-circuit, horizontal	One 10 ft		Same	A_1–A_2 36	A_2–A_3 76	A_1–A_3 112

Wood poles, crossarms, and particularly wooden braces shatter considerably under impulse sparkover. With the surge current available for these tests, no appreciable increase in shattering due to bolts or hardware was noticed, although with the high currents in lightning strokes, the establishment of multiple paths may cause a noticeable increase. Tests show a lower voltage for a sparkover through wood fibers than for surface flashover, thus increasing the tendency to splinter. With properly designed gaps, however, the path of the spark may be confined to the air as shown in Fig. 6. Tests on the gap clearances necessary to protect wood insulation checked Melvin's results (*loc. cit.*). Needle gap spacings to protect given assemblies may be obtained from standard needle gap curves and the component part curves given in this article, allowing a reasonable factor of safety.

It was impractical to make tests covering many combinations of insulation in series. The curves given, while necessarily not complete, will be of chief value in designing for preferred sparkover paths and for comparison of insulation levels.

To check the estimated values of pole top sparkover voltages, several types of straight span, 26-kv transmission poles now in use were constructed and tested. Volt-time curves were determined for flashover between any 2 conductors, and for sparkovers from conductor to grounded guy, when within range of the surge generator. As the component part curves were found reasonably accurate for estimating, tests were not made on angle or pothead poles. In all tests 8-ft copper rods simulated the conductors. Only representative values are given here as space does not permit including complete impulse curves for each sparkover path. Table I gives the dimensions of all standard pole tops tested.

A summary of the results from all pole tops tested is presented in Fig. 5. As may be noted, wooden braces on the horizontal configuration pole do not improve the line to line insulation. On the triangular configuration pole, about 40 per cent increase in line to line impulse strength is gained by using wooden braces. Because of the equilateral spacing, nothing can be gained by increased arm separation. Wooden braces on the vertical configuration pole about double the line to line insulation. At 60-in. arm spacing the minimum line to line insulation be-

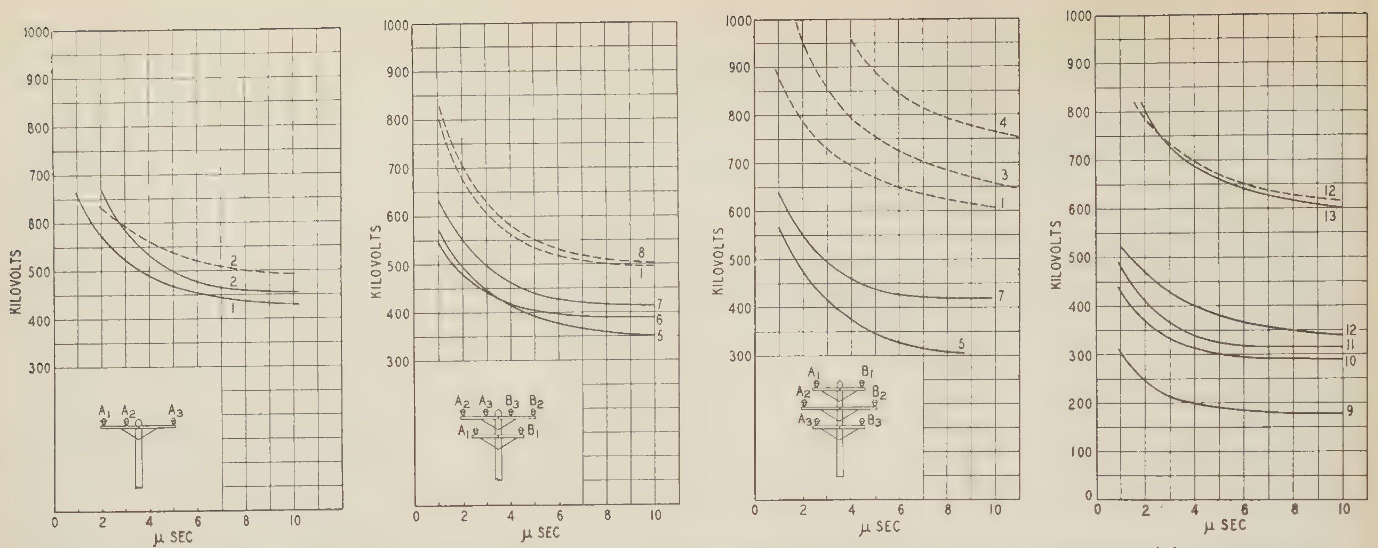


Fig. 5. Summary of minimum line to line flashover voltages for variation in 3 types of pole tops and for various guy positions; dotted curves are for wooden crossarm braces

Curve 1. A_1-A_2 standard (See Table I)
Curve 2. A_1-A_2 double arms
Curve 3. A_1-A_2 arms spaced 48 in.
Curve 4. A_1-A_2 arms spaced 60 in.
Curve 5. A_1-B_1 standard (See Table I)
Curve 6. A_1-B_1 double arms
Curve 7. A_1-B_1 long-arm brace, 60-in. spread; short, 48-in.
Curve 8. A_2-A_3 arms spaced 36 in.
Curve 9. Guy to crossarm through bolt
Curve 10. Guy to brace; 2 guy insulators
Curve 11. Guy to brace; 4 guy insulators
Curve 12. Guy between brace and crossarm
Curve 13. Typical wood strain guy insulator

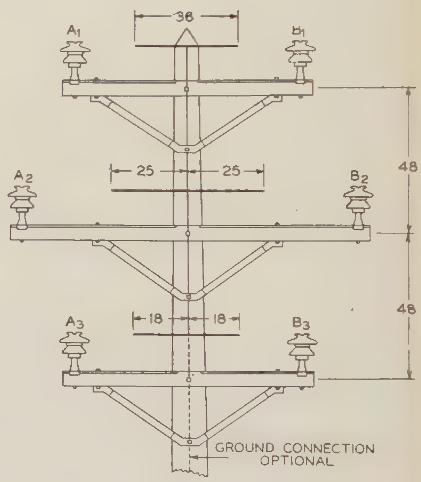


Fig. 6. Vertical configuration pole top with gaps to prevent wood from shattering

All dimensions in inches; for brace and crossarm dimensions see Table I

comes as great as can be secured, due to the fixed clearances across the 7-ft arm.

The lowest line to ground sparkover voltages for various guy positions on a pole using standard insulator spacing on a 7-ft arm also are shown in Fig. 5. It can be seen that small porcelain guy insulators add little insulation and also that guying to the double arm through-bolt is very undesirable. When line stresses permit, the guy should be attached several feet below the bottom brace. When guying to adjacent poles, as great a distance as possible should be left between the point of attachment and any ground.

Power-Follow Tests

To make a comprehensive study of the development of a power arc following an impulse breakdown would require controlling numerous factors among which are:

1. Magnitude of the 60-cycle power voltage.
2. Angle on power voltage at which the impulse breakdown occurs.
3. Length of breakdown path.
4. Magnitude and duration of impulse current.
5. Breakdown through air or solid dielectric.
6. Voltage recovery characteristic at flashover point.
7. Short circuit current available.

In this investigation, data were sought on factors 1 to 5, inclusive. The test circuit used is shown schematically in Fig. 7. Tripping potential could be varied in 30-deg steps leading or lagging the crest of the supply voltage. Short-circuit current at 26.4 kv was limited to 24.2 rms amperes symmetrical current. The voltage was controlled by a regulator in series with the 350-kva 4.8/30-kv transformer. An arrester and inductance protected the transformer winding. Gap electrodes were "copperweld" rods, $^1/_2$-in. diam. Maximum consistency in results was obtained by energizing the master trip gap and then charging the surge generator.

For a given tripping angle, the gap was widened progressively until the maximum distance at which power would follow was reached. Results of several hundred tests at 26.4 kv for gap spacings from 3 to 50 in. are shown in Fig. 8. The height of each rectangle indicates the range of variation of gap spacing for power follow, those greater than the upper limit not permitting a power arc, while those less than the lower limit resulted in an arc on every trial. The rectangle base gives the probable range of angles, taken from oscillographic records, at which the impulse breakdown took place.

The effect of varying the magnitude of the power voltage with a constant tripping angle is shown in Fig. 9. The linear characteristic indicates that other factors involved probably remained unchanged.

Breakdown Through Wood

Testing with the tripping connections to give maximum air power follow in air, wood was subjected to

breakdown with an air gap in series to prevent continuous application of a-c voltage to the wood. For surface breakdown, the power-follow distance was substantially the same as in the air gap tests. When any part of the breakdown was within the body of the wood for a minimum distance of 12 in., power follow was prevented. In many cases a shorter wood path sufficed, but the results were variable for lengths less than 12 in.

The voltage gradient necessary to maintain a discharge in a closely confined path is greater than in open air; thus by confining the discharge within wood fibers, the impulse arc is quickly deionized and a power arc prevented. Transmission line inspections have revealed many instances where crossarms and pole sections have been splintered by lightning without resulting outages.

Using various means of confining the impulse breakdown within wood, the effectiveness of wood as a deionizing agent was demonstrated. Thirty discharges of 6,000 amp each between nails driven in the center of a 4 x 4-in. cross-section gave no power arc, but shattering increased with smaller cross-sections. Trial installations of the wooden block protector are now in service; their use in the future will depend on the operating record obtained. Design details of the blocks will require further field experience, but probably will be similar to those in Fig. 10; application will be similar to that of the deion protector.

Another deionizing device for use in series with an air gap consisted of a fine wire, over 12 in. long, clamped between 2 pieces of wood; the breakdown potential is that of the series gap. Later tests with this device connected between phases of a 22-kv line showed a discharge of the line capacitance and restoration of potential without passage of power current. This device has possibilities as a back-up relief gap for substations.

Interpretation of Results

An impulse breakdown results in a highly ionized path of small cross-section. The inductance of the path being negligible, the line capacitance instantly begins to discharge. Load current transfer into the arc will be negligible during and immediately following the impulse breakdown. If the arc is to continue, the arc voltage must become and remain lower than that of the line during this brief period. Transient relations existing during the discharge of line capacitance are shown by Fig. 11. The voltage to maintain the arc rises rapidly after the impulse ceases; if it rises higher than the instantaneous circuit voltage, a condition dependent upon the point on

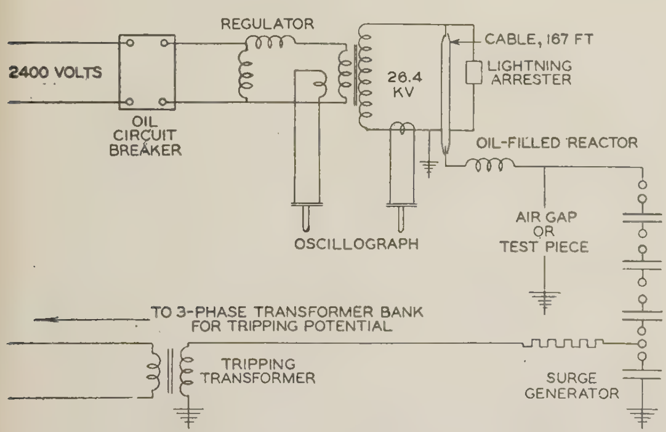


Fig. 7. Diagram of circuit used to superimpose impulse voltage upon 60-cycle supply voltage for dynamic power-follow tests

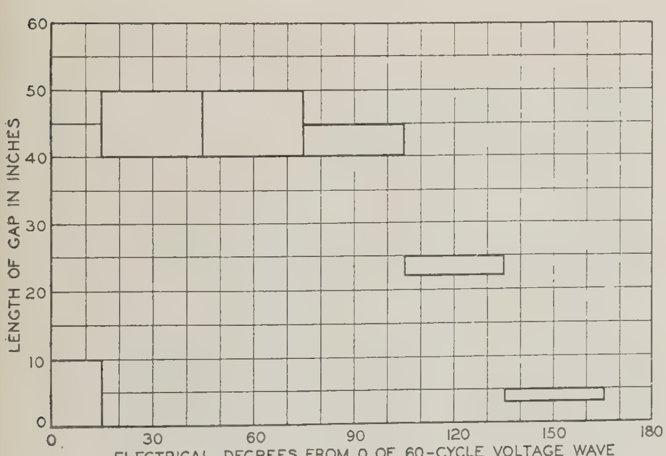


Fig. 8. Variation of power-follow distance in air with point on the 60-cycle voltage wave at which impulse breakdown occurred. The rectangles indicate the range of values observed

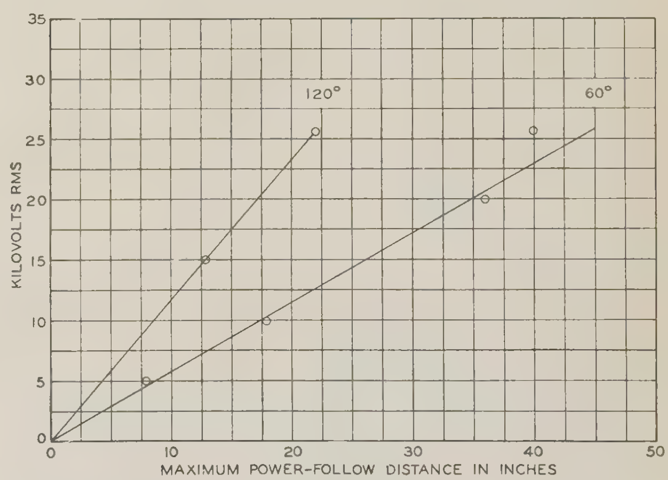


Fig. 9. Maximum power-follow distances for 2 angular displacements between crest of impulse wave and zero of 60-cycle voltage wave

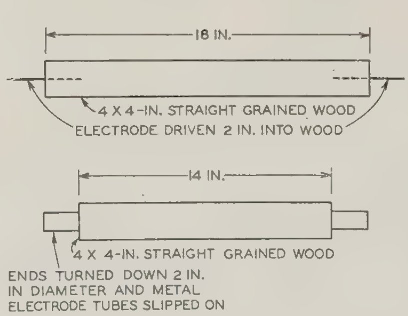


Fig. 10. Two suggested forms of wooden block lightning protectors for 26-kv lines

the 60-cycle wave of the breakdown and the nature of the path, the arc is effectually broken, the entire process taking from 200 to 400 μsec. (See "Experimental Studies of Arcing Faults on a 75-Kv Transmission System," by J. R. Eaton, J. K. Peck, and J. M. Dunham, A.I.E.E. TRANS., v. 50, 1931, p. 1469.)

If power current flows, it generally follows a transient half cycle which depends on the circuit reactance, the arc voltage, and the point of breakdown on the 60-cycle wave. The fate of the arc is determined at the first current zero and conditions at that time depend upon the current transient immediately preceding. The problem is essentially that of the extinction of a long a-c arc in air, discussed by Slepian (see "Extinction of a Long A-C Arc," A.I.E.E. TRANS., v. 49, 1930, p. 421).

Current transients for impulse breakdowns at 30 and 150 deg on the voltage wave are shown in Fig. 12. The instantaneous voltage tending to initiate the arc is the same in each case, but the ensuing current transients differ greatly: I_1 has a high maximum and decreases rapidly near 0, while I_2 has a low maximum and decreases slowly near 0. At 0 for I_1 the arc path must withstand a transient recovery voltage of about $2e_1$, while, at 0 for I_2, it must withstand only about $2e_2$.

At current 0, the deionization of a long arc in air may be considered as due to diffusion of ions from the high temperature core of the positive column to the cooler boundary regions surrounding the arc, and their subsequent recombination in this region. If this explanation be accepted, a qualitative expression for the breakdown gradient of the arc space after current zero is:

$$X = \frac{B}{a\,n_0}\,\epsilon^{\frac{c}{a}t} \tag{1}$$

Where

X = breakdown gradient in volts per cm
t = time after current 0
a = radius of arc section
n_0 = ion density at current 0
B, c = constants

Since the cross-sectional area of the arc lags behind the decreasing current, its value at current 0 will be greater, the higher the rate of current decrease. It is evident from Fig. 12 that I_1 requires a much larger arc section at maximum current than does I_2. Near current 0 I_1 decreases more rapidly than I_2. These factors give a much smaller arc section at current 0 for I_2 than for I_1. Equation 1 indicates that this variation in arc section is mainly responsible for the variation of X. Thus I_1 results in a low arc breakdown gradient and a comparatively high recovery voltage which permits long power arcs after impulse flashover, the opposite being true for I_2.

In the region near voltage 0, the power voltage was insufficient to initiate the current flow except for the short spacings noted. Since in these tests no capacitance discharged through the impulse path, the rate of current flow was determined by the difference between the instantaneous arc and circuit voltages immediately following the impulse current, divided by the circuit inductance. Near voltage 0 the arc voltage rises above the circuit voltage and the transient current flows only for short gap spacings.

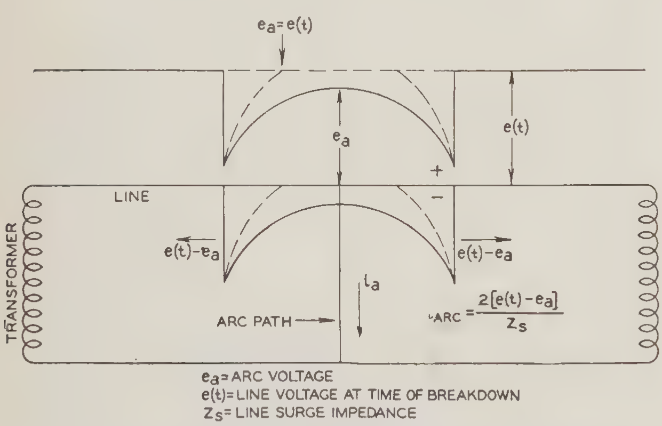


Fig. 11. Initial fast transient supplying current to the breakdown path by discharge of the line capacitance

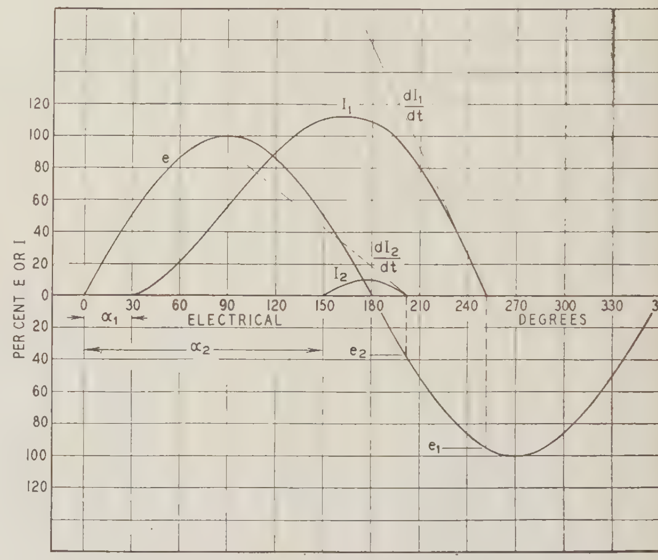


Fig. 12. Slow transient current through the arc for breakdowns at 30 and 150 deg on the 60-cycle voltage wave

Equation 1 also shows that for the actual transient currents met in practice the arc breakdown gradient curve will have a much lower initial value, and will increase much more slowly than the low transient test current. Therefore, if the conditions necessary for the establishment of the first transient half cycle are fulfilled, the arc in air will not extinguish at the first current 0. Thus the factors determining the occurrence of a power arc following lightning sparkover on a transmission line must be found in the fast transient phenomenon indicated in Fig. 11.

On a transmission line, the discharge of the line capacitance furnishes a current to the arc much greater than the initial test current described here; hence it may easily be seen how long power-follow arcs can occur in practice. A few tests on the effect of low or high impulse current during breakdown revealed no satisfactory definite trend.

General Design Principles

Data presented can be used to design a wood pole line which should give adequate lightning performance and meet local operating requirements. The following factors should be considered in the design of new lines:

1. When the importance of a line economically justifies it, improved lightning performance may be secured by the judicial use of wood and increased clearances, or by application of a dynamic arc suppresser such as the deion fiber tube arrester or a device employing the arc suppressing qualities of wood. Some type of protector is indicated as the most efficient method of suppressing power-follow arcs, since other data show that increased clearances are not to be relied upon.

2. Whichever design is followed, the pole top should be so proportioned that lightning sparkovers will occur through the air, or through the protector rather than through the crossarms or wood braces.

3. When no protectors are used, it will be advisable to make the insulation level of the line as high as possible, and also to keep the insulation level of the several types of poles uniform, in order to minimize the number of flashovers. Care, of course, should be taken to provide adequate protection for equipment at the line terminals, and for any intervening cable sections.

4. When system conditions make a ground fault preferable to one from line to line, it is desirable to make the voltage required for flashover to ground less than that required for flashover between lines. When protectors are used on a system with a grounded neutral, the duty on the protectors thus is reduced.

5. In 2-circuit lines, it is desirable to have flashovers between circuits take place between the same phases, as then no interruption will result.

One line embodying these principles has been constructed by the Public Service (N. J.) Electric and Gas Company. The deion fiber tube protector is used, one per phase, on a 2-circuit pole line with vertical configuration. Because of special maintenance requirements the top and bottom crossarms are each 10 ft long and the middle one 14 ft, spaced 4 ft on the pole. The protectors are placed on every 4th pole which has metal crossarm braces, the intervening poles having wooden crossarm braces. Care has been taken to keep the insulation on angle poles at a high level and to install protectors on adjacent poles.

Conclusions

Summarized briefly the conclusions reached as a result of this study are as follows:

1. Wood is an effective insulator for lightning voltages and should be utilized fully in transmission line design when increased impulse insulation is desired.

2. The net flashover voltages (one electrode grounded) of wood and porcelain combinations of simple pole tops can be estimated within 20 per cent from the data presented.

3. Seasoned wood has high 60-cycle insulating strength for short times of voltage application when dry, but its insulation value is greatly impaired with even a slight increase in moisture content. Creosoting has no appreciable effect on these properties.

4. Creosoting or moisture have no appreciable effect on the impulse sparkover voltages of wood.

5. Measurements of 60-cycle arcovers on wood pole tops cannot be used as an accurate indication of the impulse sparkover voltages.

6. Tests indicate that for the operating voltages under consideration, the occurrence of the dynamic arc following sparkover cannot be eliminated by increased clearances within practical design limits.

7. The fact that the dynamic arc is prevented from following the path of an impulse arc when confined within wood fibers offers interesting possibilities for field experiments.

8. Damage to pole tops by wood splintering can be prevented by application of a suitable air gap having a breakdown voltage less than that required to sparkover the insulator and wood.

9. Data are now available for designing a wood pole line with almost any practical degree of lightning reliability, economic considerations being the limiting factor.

Auxiliaries Electrified on Grace Line Steamships

ELECTRIFICATION of auxiliaries on 4 new sister ships of the Grace Line is stated to be one of the most complete ever attempted in marine service. These ships are designed for the Panama mail fleet, the first ship, the S.S. "Santa Rosa," having sailed on her maiden voyage November 26, 1932. These ships are of the twin screw, combination passenger-cargo type.

The main propelling plant on each ship consists of 2 double reduction turbine gear sets of the General Electric type, each rated at 6,000 hp normal, and 6,600 hp maximum, at propeller speeds of 95 and 98 rpm, respectively. The high pressure element revolves at 4,500 rpm and the low pressure element at 3,500 rpm. From an extension of the low speed pinion, the low pressure element of each unit drives a 500-kw 518/814-rpm 250-volt d-c generator to furnish all auxiliary power for the ship.

Under normal steaming conditions and at speeds of from 70 to 100 per cent, these generators furnish all of the auxiliary power. Each unit delivers its power to a separate bus. A turbine driven auxiliary generator of 500-kw capacity acts as a standby unit for each bus, and an automatic change-over device is provided for shifting the load when the speed of the main unit drops below the prescribed 70 per cent speed. The standby sets are motored by their own generators at about 95 per cent speed when acting as standbys and the turbines are operated with closed throttle on vacuum. An additional turbine driven auxiliary generator of 200-kw capacity also is provided for use either as a standby or for port conditions. Each of the turbine driven sets is provided with its own condenser.

The below deck auxiliary motors are practically all of the enclosed ventilated type and provided with automatic starters and wide speed control by means of field regulation. The above deck auxiliaries consisting of the anchor windlass, capstan, boat hoists, and cargo winches, are all electrically driven. The motors are of the totally enclosed type and furnished with automatic type of control. The winches, 10 of which are of 3-ton capacity and 4 of 5-ton capacity are of the worm gear noiseless type with 5 speeds in both the hoisting and lowering directions. Other departments of the ship have made full use of electrical apparatus for promoting safety, comfort, and economy.

Locomotive Operation at the Cleveland Terminal

In 2 years of operation covering more than 1,000,000 miles the 22 3,000-volt d-c passenger locomotives in use on the Cleveland Union Terminals electrification have experienced only 6 electrical failures. In this article the design and characteristics of the locomotives are reviewed briefly, and operating and maintenance data for the 2-yr period are summarized.

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OPERATION of the 3,000-volt d-c passenger locomotives on the Cleveland Union Terminals electrification has been studied after an initial period of service of more than 2 years, the line having been in complete operation since June 29, 1930. The locomotives weigh 210 tons each, and normally handle passenger trains as heavy as 1,275 tons trailing over grades as great as 1.56 per cent. Of the 1,000,000 miles of operation that have been recorded about 410,000 miles per year have been in passenger service and about 90,000 in switching service.

The facility which attended the rapid transition from steam to electric operation with the opening of the new union station and the unusually successful performance of the equipment reflected the careful planning of the management. Not only was the initial period of operation comparatively trouble-free, but also the 2 years subsequently have witnessed successful performance. A few of the inevitable minor difficulties have arisen and have been corrected, but no trouble of fundamental importance has been encountered.

Figure 2 shows the profile of the electrified line from Collinwood to Linndale, involving about 17 route miles and 56 miles of track. New York Central passenger trains are operated electrically between Collinwood and Linndale, Big Four trains between the Union Station and Linndale, and Nickel Plate trains for about 2 miles on each side of the Union Station. Power is fed to the 3,000-volt d-c overhead contact line from 2 supervisory controlled substations of 18,000 kw total capacity.

All 22 locomotives are identical, the same units being used in both switching and road service. The conditions to be fulfilled by the locomotives quite definitely fixed their general design. The necessity for starting a 1,275-ton train on the 1.56-per cent grade (1.63 per cent compensated for curvature) demanded a driver weight of about 300,000 lb. Negotiation of a 262-ft curve with train attached, called for a flexible running gear. The schedule requirements were covered by a typical run with a 1,275-ton train calling for a running time between Collinwood and Linndale, exclusive of stops, of 33 min westward and 30 min eastward. These requirements plus wheel-loading limitations and high-speed operation resulted in the design covered by Table I being adopted; characteristics of the locomotive are given in Fig. 3.

Road Service

Operation of electric passenger locomotives over a 17-mile line must involve use of the short-time capacity of the electrical equipment if its full utility is to be realized; operation of the Cleveland locomotives is based upon this fact. Examination of the profile, Fig. 2, shows that both eastward and westward runs include several heavy-grade sections. To handle the heavier trains on these portions of the line demands tractive efforts greatly in excess of the locomotive continuous tractive-effort rating. In this respect the westbound run is the more severe.

The train covered by the Terminals Company specifications consisted of 1,275 tons of steel passenger cars to be hauled between Collinwood and Linndale, with a 10-min stop at the terminal, both eastbound and westbound, a two-minute stop at East Cleveland, both eastbound and westbound, and a stop of no duration on the 3-deg and 5-deg curves on Cuyahoga viaduct, westbound only, with 10-min layovers at Collinwood and Linndale. Maximum running time exclusive of stops was specified as 33 min westbound and 30 min eastbound with an average line potential of 2,700 volts and braking at 1.0 mph per sec.

Fig. 1. One of the locomotives in use on the Cleveland Union Terminals electrification

In handling the specified train of 1,275 tons, or 15 85-ton cars, no restriction is placed on the use of intermediate (FS-2, Fig. 3) or minimum (FS-3)

Essentially full text of "Operation of 3,000-Volt Locomotives on the Cleveland Union Terminals Electrification" (No. 33-36) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933.

traction motor field strength. By limiting the operation to intermediate field between Collinwood and the terminal, and full field from the Terminal to Linndale, a train of 19 85-ton cars may be handled on the westward run with stops at East Cleveland and the terminal, but omitting the viaduct stop.

An idea of train operation through the electric zone is given in Fig. 4; this is based upon speed-current-time data taken on one section of "The 20th Century Limited" running westward from Collinwood to Linndale with a stop at the terminal. The train consisted of one electric locomotive hauling 13 cars averaging 84.5 tons each, giving a trailing tonnage of 1,100. The specific conditions of this run are quite different from contract requirements.

Switching Service

Two locomotives are used in coach yard switching and 3 in regular passenger switching in the station. Part of the coach yard trackage is on the viaduct grade which makes it necessary to have the same weight on drivers for the switchers as for the road engines. To give added flexibility to the terminal operation, it was thought desirable to have switching

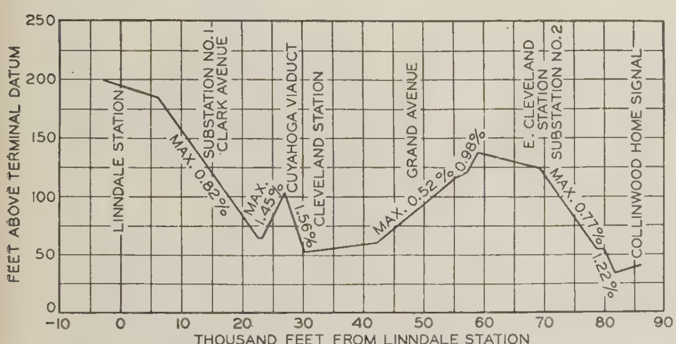


Fig. 2. Profile of Cleveland Union Terminals electrified line

locomotives suitable for road service also. Hence all locomotives are identical and therefore available for any class of work on the terminal property. The use of road locomotives in switching service has proved entirely practicable. The highly flexible running gear helps in this respect. Although the guiding truck centering device has high initial restraint, this decreases rapidly beyond about $1^1/_2$-in. displacement of the bolster, thus keeping the guiding wheel flange wear to a minimum, even in the switching work where comparatively sharp curves are encountered. The locomotive has a three-speed control which gives $^1/_3$ voltage per traction motor armature in the low speed running connection. This permits switching movements to be made with a minimum of rheostatic losses consistent with the use of high speed gearing.

Operating and Maintenance Data

In discussing the record of these locomotives to date, due allowance must be made for the limited time in service upon which the records are based. Twenty-two locomotives were purchased and went into complete revenue operation at the time of the initial changeover. At this writing (October 12, 1932) 3 locomotives are in storage because of a decline in traffic, the remaining 19 being in regular service as heretofore. Since the beginning of operation, a complete service and maintenance record has been kept for all locomotives; the following data are based upon this record.

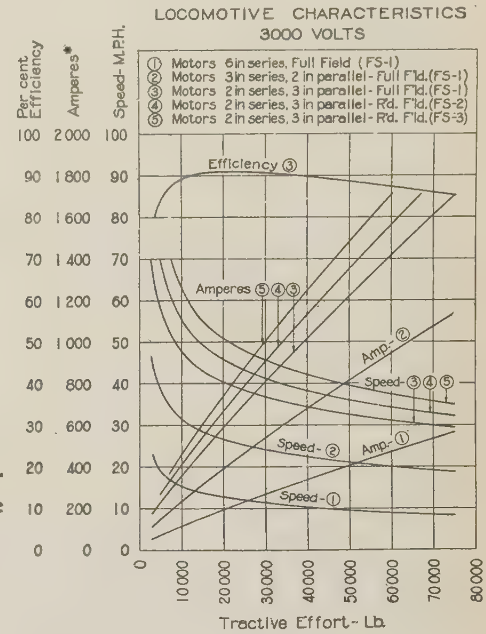


Fig. 3. Characteristics of the locomotives

Table I—Specification Data of Cleveland Union Terminals Locomotives

Weights	Pounds
Total working order	419,000
On drivers	312,000
Per driving axle, avg	52,000
Guiding	107,000
Per guiding axle, avg	26,750
Total, light	410,000
Cab, platform, and running gear	265,780
Traction motors (including gearing)	72,880
Other equipment	71,340
Traction Motors	
Number and type	6 GE-278-C
Rated voltage	1,500/3,000
Method of drive	Twin gear, cushion type
Gear ratio	74/27 = 2.741
Ventilation	Forced

Locomotive Ratings—3,000 Volts

	One Hour, Blown	Continuous, Blown	
120°C Rise by Res.	Full Field (FS-1)	Full Field (FS-1)	Reduced Field (FS-3)
Tractive effort, lb	30,600	25,500	19,200
Coef. adhesion, %	9.81	8.18	6.15
Speed, mph	37	38.5	51.5
Horsepower	3,030	2,635	2,635
Amperes	825	720	720

Tractive effort at 25% adhesion—78,000 lb

Maximum speed—70 mph

Nomenclature	2-C+C-2 419/312 6 GE-278-C—3,000 volts
Control	Type PCL (M.U.) 3 speeds full field; 6 speeds reduced field
Current collector	2 pantographs, sliding contact type
Braking	Air
Train heating equipment	Automatic oil-fired steam boiler

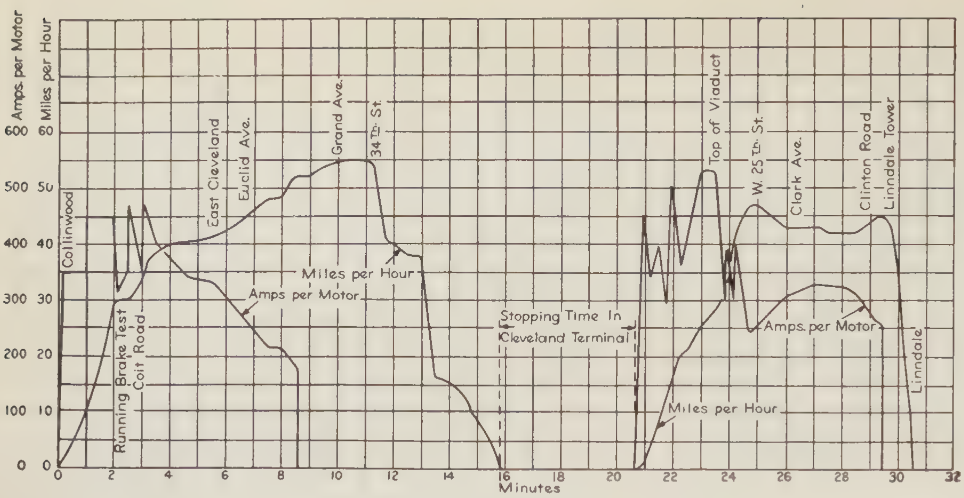
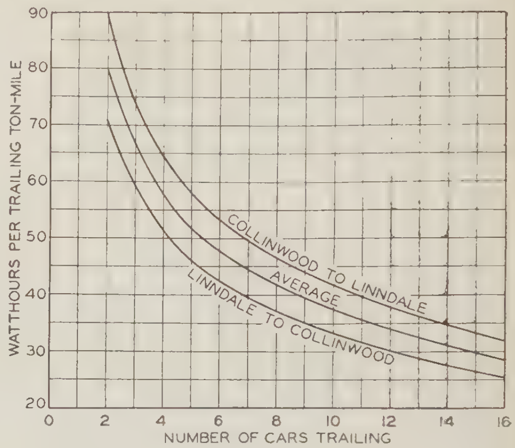


Fig. 4. Speed-current-time curves for one section of the "20th Century Limited" on a westward trip over the Terminals line

One locomotive hauling a 1,100-ton train

Fig. 5. (Below) Energy consumption curves for passenger trains made up of 82-ton cars, with stops at East Cleveland and the terminal



Mileage. The total mileage for all locomotives for the first two years of operation was slightly over 1,000,000. For the year 1931, the following locomotive mileages were recorded:

Passenger revenue miles	412,410
Switching miles in station and coach yard	89,428
Total revenue miles	501,838
Work train service miles	650
Total locomotive miles	502,488

The switching mileage given is actual odometer miles, and is reported as such because of accounting requirements of the Terminals company. It is usual practice, however, to report switching mileage at 6 mph, which would raise this item from 89,428 to 262,800 miles. In other words, the actual switching mileage in this case is equivalent to only 2.04 mph. Based on 6 mph for switching, the total revenue miles is 675,860 or 30,700 revenue miles per locomotive per year, as compared with about 22,800 revenue miles per locomotive per year based on odometer switching miles. Annual unit mileage will increase with an upturn in traffic. During the early months of operation in 1930, the locomotive mileage was at the rate of about 30,000 per unit per year, including switching miles as measured by odometer.

Availability. There are no *actual* availability data, but a reasonably close estimate can be made. On the average, 2 locomotives are in the shop at all times for regular monthly inspection and for repairs. These are actually under repair or inspection 48 hr each per week, making a total of 96 hr. In addition, each locomotive in service requires a daily inspection, followed by minor repairs, if required, which averages about $1^1/_2$ hr per locomotive, or 189 hr per week for an average of 18 locomotives dispatched each day. This makes 96 plus 189, or 285 total actual out-of-service hours per week for inspection and maintenance. Based upon this figure, the availability is 92 per cent.

Utilization Factor. Based upon the actual hours for which crews were paid, the locomotives were in service 104,555 hr during 1931. Of this total, 43,800 hr was in switching service and the remaining 60,755 hr in road service. The total locomotive hours for 1931 being 22 × 365 × 24 = 192,720, the utilization factor was 54.2 per cent. Although this is a very good showing, the utilization would be improved markedly with more traffic.

Energy Consumption. Results of energy consumption tests in road movements are plotted in Fig. 5, the test trains consisting of cars averaging 82 tons each. Values given are average watthours per trailing ton-mile for the complete run with stops at East Cleveland and the terminal in both directions. Curves are based upon maximum schedule speed consistent with observance of all speed restrictions.

Several observations of energy consumption in switching service have been made. It has been found that for the 2 locomotives in coach yard switching, where the work is almost continuous, the all day average is about 85 kwh per hour per locomotive, including auxiliaries. Subtracting auxiliary power gives a net all day average of about 55 kwh per hour to the traction motor circuits for this work. In regular train switching in the station, the all day average is about 65 kwh per hour including auxiliaries, 3 locomotives being assigned to this. However, this work is of an intermittent nature, which accounts for the lower total power consumption. The all day average to the traction motor circuits in this service is about 40 kwh per hour although the maximum hour is comparable with the coach yard average work. These figures compare with 50 to

60 kwh per hour to the traction motor circuits in heavy freight switching as determined by tests on the New York Central and the Delaware, Lackawanna & Western railroads.

Brush Wear. From present available data, traction motor brush life will vary between a minimum of 50,000 miles and a maximum of 100,000. As so many of the original brushes are still in service, definite figures cannot be given yet.

Hub Liner Replacement. In 1931, 110 hub liners were replaced. About $^3/_4$ of these were on the drivers and $^1/_4$ on the guiding wheels. No mileage records have been set up for hub liner replacement.

Pantograph Strip Wear. In operating trains in 1931, both pantographs were used, making a total of 8 strips (copper) in use simultaneously on each locomotive. Average mileage per replacement was about 8,000.

Traction Motor Overhaul. Because of the limited period of operation so far, the traction motor overhauling schedule has not been started. Commutator wear is negligible to date. Wear of axle and armature linings to date also has been almost negligible. These bearings are of the constant oil level type, which maintain an approximately constant depth of oil in the waste chamber until the supply in the large capacity reservoir adjacent to the bearing is exhausted.

Failures. In the first 2-yr period of operation, there were 12 engine failures causing delays of 3 min or more. Six of these were classed as man failures, caused largely by the inexperience of the crews in handling the new equipment. The other 6 were classed as electrical failures, giving about 170,000 locomotive miles per electrical failures. No failures occurred from mechanical causes, nor were there any cases of hot bearings in either journals, traction motors, or auxiliaries.

In the winter of 1931–32, unforeseen trouble was experienced from unseasonable lightning storms which on 4 occasions caused minor damage to the electrical circuits while the lightning arresters were out of service. It is proposed to remedy this condition by operating arresters (aluminum cell type) throughout the winter and provide means for heating them to prevent freezing of the electrolyte.

A Summary of Year's Insulation Research

INSULATING oil, capillary action of oil as related to paper, and properties of impregnated paper were discussed in considerable detail at the sessions of the committee on electrical insulation of the division of engineering and industrial research of the National Research Council, held in conjunction with the Institute's Middle Eastern District meeting, Baltimore, Md., October 10–13, 1932. A joint session under the auspices of the A.I.E.E. and the National Research Council was held, abstracts of these papers having been presented in ELECTRICAL ENGINEERING for September 1932, p. 659–60.

Two separate sessions of the committee on electrical insulation of the National Research Council also were held. Summaries of these sessions, prepared by Dr. J. B. Whitehead, chairman of the committee, and W. A. Del Mar, vice-chairman of the committee, are presented herewith. Following these summaries, authors' abstracts of the various papers are presented. This treatment supplements the annual report of the chairman of the committee on electrical insulation which appeared under the title of "A Résumé of Progress in Insulation Research" on p. 675–8 of ELECTRICAL ENGINEERING for November 1932.

Annual Meeting of the Committee on Insulation

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LOOKING BACK at the recent annual meeting of the committee held in Baltimore, it is possible to segregate the material presented in the various progress reports of research into a few groups which indicate the directions in which recent research effort has been directed. As has been usual in past years, the points of departure in nearly all cases have been the problems of practice. Even in those instances in which the work has been done by physicists

and chemists, and so is of more fundamental character, there is distinct evidence of effort to link the work with some of the more common manifestations of dielectric behavior as found in practice.

As a first group may be mentioned a number of papers, some dealing exclusively, and others partially, with insulating oils. Two efforts have been directed particularly to a study of the conditions under which wax forms in the oil of impregnated paper cables, this highly complex question remaining one of the outstanding problems in the operation of the so-called solid cables of today. One of these deals with the influence of ionic bombardment of various types on the electrical characteristics, as well as on the evidence of wax and other degradation products; and the other study is using X-ray analysis as a method for investigating the amount of wax formed in the oil. Closely related to this group were 2 papers describing highly sensitive bridges and special types of test cell, in which measurements may be made on very small samples of oil in very pure state, the bridges affording the necessary high sensitivity required in the measurement of such small pure samples. Sensitivities at 60 cycles of the order 5×10^{-7} power factor are reported, and adaptation to frequencies up to 10^5 cycles.

Closely related to the oil studies was a group of reports on the capillary action of oil as related to paper. Two of these were directed to a study of the conditions under which cellulose fiber is wetted by the oil, and other questions relating to the mechanism of impregnation. The impregnation of fibrous cellulose materials with the organic impregnating compounds is shown to resemble the process of absorption of water by cellulose. Another study dealt with the rates of rise of a number of different oils in a number of different cable papers, and it was shown that this phenomenon obeys accurately the law governing the rise of liquids in small capillary tubes. Each paper therefore has a definite effective capillary radius. Moreover, a definite relationship seems to exist between the effective capillary radius and the Gurley air resistance of the paper. Another interesting result is that when calibrated with a liquid for which the constants are known, the rate of rise of any liquid in a paper strip may be used for the determination of the surface tension and the viscosity of the liquid. Much new light is thrown upon impregnation processes in this group of papers.

A third and very important group was that dealing directly with the properties of impregnated paper. Two of these deal with paper impregnated carefully under laboratory conditions, and so deal with basic properties. In one the variation of loss and capacitance factors over a wide range of frequency and temperature was studied and it was shown that present accepted theories for explaining dielectric loss do not appear sufficient to account for the experimental results in the range studied. In another report careful measurements at 60 cycles and over the usual range of temperature in cable operation have shown for the first time that the increase in dielectric loss and power factor of impregnated paper, over the values for the constituent oil and paper, are definitely related to the original electrical properties of the oil. One component of the increased losses is shown to be directly proportional to the conductivity of the oil, and another component, due to reversible absorption, is shown to be a definite function, over a number of oils, and over the range of temperature studied, of the product of the viscosity by the conductivity of the oil. This product has been designated the "electrical purity" of the oil and is proposed as a gage of the behavior of an oil when used to impregnate paper. Of particular interest in this group was a series of accelerated life studies on paper as impregnated with different oils. The preliminary evidence in these studies indicates that there is a definite relationship between the life of the impregnated paper and the penetrativity of the oil as dependent upon the viscosity and surface tension, as deduced from the capillary experiments referred to above; and further that as between oils of different origin, other conditions being equal, there may be pronounced differences in their stability under electric stress, as shown by accelerated life tests. Particular interest attaches to these studies in the fact that in using thin oils, the conditions obtaining in oil filled cables are closely approximated. These laboratory studies thus approach more closely than is usual the conditions obtaining in practice.

Cable Developments Discussed by Committee

By
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FELLOW A.I.E.E.

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CONTINUAL warfare is being carried on in numerous research laboratories against that arch enemy of high voltage cables, ionization. The cable in process contains air, so that the conditions on which this enemy would thrive are present and must be driven out in the beginning. From then on, there is no let-up in the fight to keep it out.

The shock troops in this war are the manufacturing and operating engineers. Behind them are the college and other laboratories, preparing weapons to be used later at the front. It is this work behind the lines, and in its preliminary stages, that is reported at the meetings of the electrical insulation committee of the National Research Council. If one could have a cable with dielectric of zero temperature expansion and an elastically tight sheath, these researches might be stopped without great loss to the industry. It is principally in the effort to compensate for the absence of these ideal features that this work is significant.

The problem of making a cable without ionization has been solved. Dr. Whitehead's work shows us such an ideal cable and tells us its properties. The

best factory-made cables are substantially equal to it, if neither bent nor cooled, and if the ends are not exposed to air. The present problem is either to keep the cables in their original ideal condition, without resort to elaborate field accessories, or to make them immune to the effects of ionization.

The former method of attack is largely a matter of physics and the latter, of chemistry. Hence we are not surprised to find that the insulation committee is now divided into sub-committees on physics and chemistry.

An important sector of attack on the physics front concerns the "wetting" of paper by impregnating compound. It is well known that when the oil in a cable contracts, its distribution in the space which it no longer fills is a matter of concern. This distribution depends both upon the "spreading tension" of the oil on the paper and on the "tensile strength" of the oil itself. McLean and Kohman found that the wetting properties of oil may be evaluated by the rate of penetration or rise of oil in vertical paper strips. This rate is plotted against the reciprocal of the rise and the slope of the curve gives a measure of the "spreading tension." Further work by Kohman suggests that practical methods for improving the spread of oil may result from treatment of the paper prior to impregnation.

Hubert H. Race, working on dielectric losses at high and low frequencies, reached the tentative conclusion that the major part of the losses lies neither in the oil between fibers nor inside the fibers; but that it is a surface effect associated with the wetting of the paper fibers by the oil. Data were given supporting the view that, in the impregnating process, the oil does not penetrate into the fibers.

The general laws of capillary rise of oil in paper were reported by J. B. Whitehead and E. W. Greenfield, whose work will assist future developments bearing on oil distribution in cables. Particularly valuable is their introduction of the "effective capillary radius" as a measurable physical constant of paper.

No amount of improvement in the spreading tension will prevent voids entirely, so that it is necessary to consider what happens in voids under stress, in order that steps may be taken to protect the cable against inevitable destructive tendencies.

Where a void space occurs in a high voltage cable, certain phenomena take place which indicate the occurrence therein of streams of electrons. Work by W. H. Bennett shows that electron emission has high penetration through solid dielectrics. In one of his experiments, steady currents of 4 ma per sq cm were passed through pyrex glass without rupture, when the surface of the glass was bombarded by electron emission from a cold cathode.

One of the evidences of electron bombardment is the occurrence in cables of "X," an insoluble solid oil product which has not been made outside of cables by any means other than bombardment of oil with electrons, usually from cathode ray tubes.

Attention was called by W. A. Del Mar to the fact that dendrites in cables almost invariably occur on the concave side of the paper tapes and that the first visible step in dendrite formation is the generation of "X." These circumstances suggest the presence of electron streamers spreading outward from craters associated with the voids which appear to precede dendrites.

Clark and Mrgudich have started a study of "X" formation and discovered the presence of colloidal paper fibers within the paper tapes, the colloidalization of the paper being most intense in the regions of highest electric stress. K. S. Wyatt reported rise of power factor as a result of electron bombardment. Another important contribution by Mr. Wyatt and his associates is evidence that the aging of cable is due, in part, to air which gains access to the insulation either before or after installation, and travels longitudinally in the cable. The evidence is derived from oxidation tests of the oil, especially the "spread test" which tells the degree of oxidation of oil by the rate at which it spreads over a surface of water.

The work of Dr. Whitehead in preparing a summary of the year's literature on dielectrics is most valuable. (See ELECTRICAL ENGINEERING for November 1932, p. 765–8.) Reference has been made to his experimental work on "perfect cable." In the course of this work, the influence of various materials and processes is reported. The conclusions apply only to the "perfect cables" and their significance in relation to the normal product is not yet known.

C. L. Dawes showed and explained the hitherto unknown relation between dielectric loss or power factor and frequency. The dielectric loss is equal to a constant, plus a constant times the frequency, both constants depending on the paper, oil, temperature, and cable geometry.

Other excellent work of C. L. Dawes, J. C. Balsbaugh, E. J. Murphy, G. T. Kohman, and others working on more purely scientific and metrical aspects of the problem, will bear fruit in its turn.

Salient Points From N.R.C. Insulation Papers

AUTHORS' abstracts of papers presented at the sessions of the committee on electrical insulation of the National Research Council held in Baltimore, Md., October 11 and 12, 1932, follow. Requests for additional information should be addressed to National Research Council, 29 West 39th Street, New York, N. Y.

I—Insulating Oils

X-Ray Studies of the Insulating Materials in High Tension Cables, G. L. Clark and J. N. Mrgudich, University of Illinois, Urbana, Ill.

The phenomenon of the formation of waxy material within oil impregnated high voltage cables during stress has been one of the

objects of this investigation. By the use of a beam of monochromatic X-rays and suitable control standards containing known percentages of wax, semi-quantitative determinations of the amount of wax in an oil may rapidly be made.

The more important observations that were made during the course of the investigation follow:

1. The variation of the wax content of a stressed cable with the magnitude of the stress to which the cable has been subjected seems to be a direct relationship.
2. The wax content of a stressed cable, although nearly uniform for points further from the conductor than approximately one millimeter, increases sharply close to the conductor, being usually double or treble the value of the wax content near the center of the insulation.
3. Heating decreases the percentage of wax within the cable.
4. The wax content of the previously stressed cable slowly decreases with time as the cable remains unused.

Another phenomenon associated with stressed cables is the newly discovered presence of colloidal paper fibers within the paper tapes of the conductor. Although the investigation of this effect has not been as thorough as could be desired, due to lack of time, it has been noticed that the magnitude of the colloidalization of the paper is greater near the core of the cable and decreases more or less linearly to a small value at the sheath. A large amount of research, both on the wax and the colloidal paper problems, remains to be done.

Breakdown of Glass Under Cold Cathode Discharge, W. H. Bennett, Ohio State University, Columbus, Ohio.

In the course of experiments on cold cathode discharges as related to the design of very high voltage tubes, begun by the author while a National Research Fellow of physics at California Institute of Technology, and continued since becoming a member of the permanent staff at Ohio State University, several observations have been made which shed light on the process of the breakdown of glass under electric stress.

In one experiment, electron emission was being drawn in high vacuum from a cold cathode (which was a sharp metal point at room temperature) by the application of an electric field at the tip of the point, of the order of 10,000,000 volts per cm. The tip of the cathode extended through a hole in the upper one of 2 parallel metal plates. The upper plate was at the same ground potential as the cathode, while the lower plate was at various positive potentials up to 20,000 volts. A magnetic field of intensities up to 6,000 gauss, was applied at right angles to the direction of the electric field in the vicinity of the cathode. The faces of the magnetic pole pieces were just outside the tube walls, and of course in planes perpendicular to the planes of the plates in the tube. Electric lines of force extended roughly from the cathode and upper plate toward the pole pieces.

When the tips of the cathode extended into the region between the plates, and a strong magnetic field was applied, the electron emission from the cathode could not go directly to the anode, but spiralled around the magnetic lines of force, striking the glass walls of the tube in spots about 0.5 mm in diam, giving a bright yellow or white luminescence. This electron emission was mostly turned back from the glass, finally reaching the anode but, under certain conditions, some of the current went through the glass wall and could be collected with a probe placed just outside the tube. The discharge outside the glass appeared as a tiny bluish corona streamer, when the current was between 1 μa and 10 μa, but currents of 0.02 μa were detected with the probe when no corona streamer could be seen. The currents to the anode were of the order of 100 μa.

The glass used in the tube was pyrex. Bombardment of the walls did not affect the high vacuum appreciably, showing that no cracks or holes were developed by the bombardment. After the completion of the experiment, it was found that the bombardment had developed faint cracks and pits on the inner side of the wall, and that the wall in these regions was mechanically weaker than other parts.

This is an instance where a current of 10 μa has been driven through a comparatively restricted volume of glass without rupture at a potential much less than that necessary to produce rupture under the usual conditions.

In another experiment cold cathode emission was directed at a thin glass disk back of which lay the anode. The disk was the kind used commonly as cover glasses for bacteriological slides. Both sides of the disk were in high vacuum but one side was lying directly on the anode. No appreciable current could be passed through the glass disk without cracking it, as long as no magnetic field was applied, but when a magnetic field was applied in such a direction as to bend the electron stream away from the normal to the anode surface, currents of 20 μa could be drawn from the anode without producing any effects on the disk which could be found with a microscope later. During such discharge, a faint bluish fluorescence could be seen on the surface of the glass disk displaced somewhat from the place directly opposite the cathode. Conclusions to be drawn are:

1. Steady currents of 10 μa have been passed through pyrex glass at reduced voltages, without mechanical rupture, when there was an ionizing agency present, *viz.*, the 20,000-volt X-rays due to bombardment of the inner surface.
2. The current density in this case was at least 4 ma per sq cm; the power delivered to the conducting part of the glass was probably of the order of 0.02 watt.
3. In high vacuum, electron currents can pass from a cathode to a glass surface and then be diffused or reflected from there back into the evacuated space in the tube, but for a current to pass through glass, opposite charges must be supplied to opposite surfaces of the glass.

Progress Report on Deterioration of Oils and Papers Under Corona Discharge, K. S. Wyatt (A'22), Detroit Edison Company, Detroit, Mich.

This work forms part of an investigation of cable deterioration by The Detroit Edison Company carried out by the research staff under the direction of Dr. C. F. Hirshfeld (A'05). The study of the effects of corona discharge on oils and papers followed the early finding that the major cause of deterioration of oil impregnated paper high voltage cable insulation was ionization. As an outcome of a comprehensive investigation it was hoped to obtain a combination of oil and paper which would have, in addition to low loss and other usually desirable characteristics, maximum stability to ionization and thus increased operating life.

The work on oils, after a series of studies of the electrical characteristics of pure hydrocarbons and commercial oils from various crudes and determination of their gas-forming and wax-forming characteristics under cathode ray bombardment (Coolidge tube), finally resolved itself into 2 distinct lines of attack. One consisted of an experimental inquiry, carried out at Cornell University, into the mechanism of the reactions of hydrocarbons in electrical discharge; this involved the use of the mass spectrograph. The other (at Detroit) consisted in the study of the changes in electrical characteristics of oils and papers after subjection to corona discharge under conditions similar to those occurring in cable operations; it is with this work that this progress report is concerned.

Last year an apparatus was described consisting of a bombardment chamber together with a power factor measuring cell with which the changes occurring in 2 oils, one a purified water-white oil, the other a commercial cable oil, after subjection to corona discharge, could be followed. It was reported that appreciable increases in loss occurred after a few hours' bombardment of the highly purified oil and that this did not appear to be due to impurities contained in the oil or on the walls of the apparatus, or to traces of air remaining in solution.

This year, after further confirmatory experiments had been made it was found possible to distil these oils after bombardment, without danger of cracking, by means of a high vacuum still designed by Dr. Kenneth Hickman. Continued bombardment of the distillate showed very small increases in power factor. It is possible, therefore, that the appreciable increase in power factor previously reported was due to either traces of impurities or, more probably, to traces of dissolved gases in the oil which the high vacuum (10^{-5} mm) distillation removed. The generally held belief that hydrocarbons, if pure, suffer no appreciable changes in dielectric loss with electric discharge if air is rigidly excluded may have a basis in fact.

The residue oil, when dropped on the surface of water (Adam film pressure balance), was found to spread somewhat, indicating the presence of traces of oxidation products. The distillate possessed no spreading characteristics.

The water-white oil, after bombardment, contained large quantities of particles visible under the ultra-microscope. These apparently are polymerization or condensation products, the first stages of wax formation.

Subsequent work leads to the belief that extremely small quantities of air may cause appreciable increases in dielectric loss under conditions of corona discharge. The findings which lead to this belief will be checked carefully in further experiments.

Oil impregnated paper is subjected to discharge in an apparatus designed to eliminate variables as far as possible. Preliminary experiments with a commercial cable paper and a water-white oil indicate that a considerable rise in power factor (1.18 per cent to 4.59 per cent) occurs after 24-hr bombardment. This is attributed partly

to impurities in the paper. Traces of dissolved air may also have contributed to the increase in loss; in further experiments this variable will be eliminated.

An exceedingly delicate test for oxidation products in oils is that involving their film forming characteristics on water. The test has been developed and applied to oils taken from cables in service. (An Adam film pressure balance was used.) Samples of oil were taken from different radial points between conductor and sheath of new and used cables with the following results:

1. Oil from new cables gave a curve for film spread which was flat across the entire radius and of low value.
2. Oil from cables from service and from accelerated aging tests frequently gave a U-shaped curve, the minimum values of which were considerably higher than that for new cable.
3. After a new reel of cable had once been cut in 2, even though the ends were lead sealed immediately, the curve for film spread *vs.* radial distance from the conductor of a sample taken several feet from the lead seal would turn upward at both sheath and conductor after a short time of storage.

The tentative conclusion that may be drawn from work done so far is that aging of cable in service or on test is in part due to air which gains access to the insulation either before or after installation and travels longitudinally along the conductor or filler spaces. Various evidences indicate the U-shaped radial curves for film spread are due to oxidation, although absolute proof is difficult to obtain.

Another interesting phenomenon of oils from used paper-insulated non-rosin cables is that of the "secondary spread." The original spread of an oil (diluted with benzol), due to its content of oxidation products, reaches a definite value in less than one min without further spread. The oil from used cables, however, continues to spread further, sometimes at a rate sufficient to be visible. The effect is due to rapid oxidation. The following points have been established:

1. The secondary spread is most rapid for oils from used cables.
2. The effect is present to lesser extent in the oil from new cables.
3. The original impregnating oil possesses negligible secondary spread.

Experiments with oils bombarded with cathode rays in vacuum and in contact with paper lead to the following conclusions:

1. The impurities in the paper are a factor in causing oxidation of thin films on water as evidenced by secondary spread.
2. Cathode ray bombardment greatly increases the secondary spread.

In conclusion it may be stated that there is now some doubt as to whether the excellent electrical characteristics of a pure hydrocarbon oil, entirely free from air, are impaired by subjection to corona discharge. Small traces of air appear to cause relatively large changes in power factor under conditions of ionization. In cable operation, small traces of air appear to gain access to the insulation, causing deterioration. Oil which has been removed from cable oxidizes more readily than the original oil; rate of oxidation is greater if ionization has been present in the cable.

II—Sensitive Measurements

Dielectric Study at the Harvard Engineering School During 1931–32, C. L. Dawes (M'15), Harvard University, Cambridge, Mass.

During the past year research on dielectrics has for the most part been confined to the studies of ionization itself, although the analysis of the dielectric characteristics of impregnated cable paper has also been continued. Also, considerable time has been devoted to the construction of a new high voltage dielectric bridge. The fundamental circuit connections of this bridge are identical with the earlier ones that have been developed in our laboratories. In this bridge, however, the range of flexibility and the rapidity of manipulation have been greatly increased; also the insulation and design are such that with very high voltages absolute safety to the operator is assured.

In the study of ionization of air, the work has consisted chiefly of extending the ranges of pressure, gap length, and frequency. For example, except at very near the ionization point, the power is still found to be a linear function of the current; a very small correction term appears to account for the departure from the linear relationship. The power loss is independent of temperature except in so far as the temperature affects the pressure. The values of the maximum voltage gradient are proportional to the absolute pressure.

The power and the power factor vary with the frequency. With solid dielectrics the power varies as a linear function of the frequency over commercial frequency ranges. With ionized gases, however, no such relationship appears to exist. Over the range of frequencies observed, the variation of power with frequency is not large and relative maximums and minimums exist. For example, with certain gap lengths a relative minimum occurs at 50 cycles and a relative maximum at 60 cycles. With cables having ionization this same effect has been found to exist; with the cables, however, the frequencies for relative maximums and minimums somewhat differ.

Further analysis of the electrical characteristics of cable paper impregnated with various compounds has been made. The power-temperature characteristics for constant potential gradient and various frequencies, and for constant frequency and various potential gradients is found to consist of two components A and B. Up to the critical temperature of approximately 50 deg C, the entire power is represented by a single component A, when $A = aT^n$, T is the temperature in deg C, and a and n are constants.

Above the critical temperature the power is given by $A + B$, where B is a second component equal to $B = bT^p$, where b and p are constants. It was also found that at times B was negative.

The foregoing relationship has been found to hold in every case for a constant potential gradient of 49.2 kv per cm (125 volts per mil) at all frequencies. Only at very low voltage gradients an occasional slight departure from this law was found.

Further Studies and Tests on the Problems Involved in High Precision Power Factor Measurements of Small Oil Samples, J. C. Balsbaugh (A'23), Massachusetts Institute of Technology, Cambridge, Mass.

The initial object of this research was to develop a bridge capable of measuring a power factor of a small oil sample to a power-factor precision of 10^{-6} and to develop a satisfactory oil cell. A paper describing this bridge was presented by J. C. Balsbaugh and P. H. Moon at the meeting of the committee on electrical insulation at Harvard University in November 1931.

In a paper, "Losses in Air Condensers," presented by J. C. Balsbaugh and P. H. Moon at the meeting of the committee on electrical insulation at Harvard University in November, 1931, it was suggested that the absolute power factor of air-condensers forming a part of power-factor measuring bridges was in the range of 10^{-6}. Since a power-factor measuring bridge measures the difference in the absolute power factors of the 2 capacitances forming the high voltage arms of the bridge, obviously to measure the power factor of an oil cell in one arm to a desired precision requires the evaluation of the absolute power factors of all the capacitances in the high voltage arms to the same precision.

For the evaluation of the absolute power factor of an air condenser a set of 4 cylindrical condensers similar in construction have been made. These cylindrical condensers are made of brass tubing with the usual shield, measuring, and high voltage sections. These condensers have approximately equal capacitances but have different spacings and surface areas. In these condensers the insulation between shield and measuring sections has been very effectively shielded so that no electrostatic lines can pass through this insulation between high voltage and the measuring section. The surfaces of the high voltage and measuring sections in all the condensers are rubbed first with a fine emery cloth to remove any oxide from the surfaces and are then cleaned with carbon tetrachloride. These 4 condensers are then arranged so that they are connected individually into one of the high voltage arms of the bridge. The other high voltage arc consists of 2 variable condensers in parallel. Thus by balancing each of these 4 condensers individually against the other high voltage arm the difference in the absolute power factors between any of these 4 condensers may be obtained. These data will permit an evaluation of the absolute power factor of each of the 4 condensers. Then knowing any one absolute power factor, the absolute power factor of all the high voltage capacitances may be found.

It has been found that the absolute power factor of an air condenser is dependent upon the voltage gradient, surface area and the nature of the surfaces. The absolute power factor of an oxidized brass condenser has been found to be as high as 10^{-4}.

There has also been developed in this research an oil cell that may be used for measuring the power factor of highly refined oils or synthetic hydrocarbons. The conducting surfaces of this cell consist of nickel cylinders. This will permit heating of these cylinders by induction after the cell is installed in the oil system, and thereby obtain a clean and gas-free surface. These nickel cylinders are enclosed in a pyrex glass tube with sealed leads so that an effective evacuation may be obtained. Another feature of this cell is a metal

cylinder sealed into the glass tube so that any surface leakage or conduction current through the glass may be eliminated from the measuring section of the cell.

Further studies and tests have also been made on the necessity of phase balancing of the shield circuit on the power-factor precision of the bridge. It can be shown theoretically that phase balancing is unnecessary only when the phase shifter is very accurately set, when the power factor of the capacitance between the measuring and shield sections is zero and when the difference in capacitance between measuring and shield sections on the 2 sides of the bridge is relatively small. It can be shown in general, also, that the accuracy of shield balancing in any case is directly proportional to the difference in the capacitance between measuring and shield sections on the 2 sides of the bridge where a single shield bridge is used. It is therefore suggested that in a bridge for high-precision power-factor measurement that variable condensers be installed.

A Portable Power Factor Apparatus for Studying the Deterioration of Insulation, F. C. Doble (A'12), Doble Engineering Company, Medford Hillside, Mass.

A portable apparatus for measuring power factors of insulation down to 0.1 per cent and up to 10,000 volts at 60 cycles was described. It was pointed out that a valuable feature of the apparatus is that it utilizes direct reading instruments and so permits great saving in time as compared with the usual laboratory bridge for making measurements of this character. A reading can be made in a few seconds.

The apparatus consists of 3 sensitive direct reading instruments (ammeter, voltmeter, and wattmeter) and 60 cycle 110 to 10,000 volt transformer, as source of power, all in a circuit carefully shielded and compensated for internal loss and protection against external inductive influence. The wattmeter is of the dynamometer type with a pivoted moving coil. The ammeter has 4 sensitivities giving full scale deflections of approximately 150 to 4,000 μa. Taking as the smallest value of watts that of one division, 0.02 watt, the power factor for full scale deflection on the ammeter would be 0.05 per cent.

The accuracy of a complete measurement with the portable apparatus, including both the errors of observation and the instrumental errors, is shown by a table compiled from a series of measurements on 8 different samples made by Prof. C. L. Dawes of Harvard University. The average accuracy is 97.2 per cent or the error is 1.4 per cent plus or minus.

It was stated that the instrument had been used in more than 25,000 field tests over a period of 3 years and that many instances of defective insulation have been discovered before failure. Instances were reported in which it was possible to follow changes in power factor during a 10-min period.

Bridge and Condensers for the Precision Measurement of Dielectric Constant and Power Factor at Frequencies Below 10^5 Cycles per Second, A. V. Astin.

In connection with an investigation on the electrical properties of insulating liquids at the Bureau of Standards supported by the Utilities Research Commission, Inc., of Illinois, an a-c bridge has been constructed for the precision measurement of the dielectric constant and power factor of liquids. The bridge is primarily for low voltages and can be used at any frequency below 10^5 cycles. It is probable that its upper frequency limit is much higher, but as yet no attempt has been made to use it at higher frequencies.

The bridge is similar to a symmetrical Schering bridge but with the source and detector interchanged from the usual arrangement. This interchange permits the use of a Wagner ground and a simplified shielding system, 3-electrode instead of 4-electrode condensers for standards and test cells, and a detector at ground potential. The balancing of the bridge proper is done entirely by the variation of capacitance. An interchange of source and detector in a Schering bridge demands a high impedance detector if full sensitivity is to be retained. This requirement is met by using a vacuum tube as the input impedance. The detector consists of a 2-stage or 3-stage resistance coupled amplifier with a vibration galvanometer as the indicator in the commercial frequency range and a specially designed vacuum tube voltmeter as the indicator for higher frequencies. This voltmeter contains a filter circuit to reduce the effect of harmonics, and has a linear response so that there is no loss of sensitivity when it is used as a null indicator.

The test cell is a 3-electrode condenser in which lead and insulation corrections are eliminated. It is designed for vacuum work. Its air capacitance is about 600 $\mu\mu$f and its liquid capacity about 150 cu cm. The standard condenser is also of the 3-electrode type, and its capacitance is continuously variable between 100 and 2,000 $\mu\mu$f. A micro-condenser having an overall change of 0.1 $\mu\mu$f is used in parallel with the standard for accurate balance.

The sensitivity of the bridge is such that power factors as small as 5×10^{-7} can be detected, dielectric constants determined to 0.01 of one per cent, and variations of dielectric constant of 0.00001 of 1 per cent observed. Its sensitivity to dielectric constant changes is comparable to that of heterodyne methods.

III—Capillary Action

The Time-Lag in the Breakdown of Paper at Constant Potential, E. J. Murphy and G. T. Kohman, Bell Telephone Laboratories, Inc., New York, N. Y.

It is known that the breakdown voltage of paper and of other insulations is a decreasing function of the time of application of the voltage. The present work was undertaken to obtain evidence as to the nature of the processes which produce this phenomenon in the case of direct potentials. The methods used involved a study of the residual charging and discharging currents at voltages ranging from 50 to 600 volts. In general the delayed breakdown might result from at least 3 possible processes:

1. Gradual increase of temperature due to Joule heating.
2. Gradual formation of polarizations of long relaxation time which breakdown into free ions when a certain degree of separation of the charges concerned has taken place.
3. Formation of a high potential gradient in the regions adjacent to the plates of the condenser as a result of the electrochemical reactions which take place there during the passage of current.

The second of these possibilities is considered to be eliminated by the results of the present work, and the evidence available points to the third as the actual process which results in "delayed breakdown" of paper insulation under constant potential. The rate of formation of the high potential gradient regions near the electrodes depends upon the rate of electrolysis, and this in turn decreases if the moisture content or the amount of water soluble material in the paper is decreased. A few data are given suggesting that as the paper is dried the "delayed breakdown voltage" (i. e., any breakdown voltage obtained after application of the voltage for a considerable time) tends to approach the instantaneous breakdown voltage. The results also suggest that a correlation may be found to exist between the life of a paper condenser or insulation subjected to a given constant potential and the "true conductivity" of the paper. By true conductivity is meant the conductivity calculated from the value of the current which prevails after the potential has been applied for a long enough time that polarization currents are comparatively negligible, but not so long that appreciable changes in the resistance of the condenser are produced by the electrolytic process mentioned above. The conclusions are not applicable to alternating potentials.

Measurement of Degree of Wetting by Penetrability Studies of Certain Fibrous Dielectrics, D. A. McLean and G. T. Kohman, Bell Telephone Laboratories, Inc., New York, N. Y.

It has been recognized that the quality of impregnated dielectrics such as those used in power cables depends to some degree upon the completeness of the impregnation process. The natural property of such a heterogeneous system which affects the completeness of impregnation is the tendency which the liquid impregnant has to wet the solid material.

Although the general theory of wetting has been quite satisfactorily worked out, little is known concerning the wetting of cellulose by liquids. The most formidable obstacle in the way of obtaining such information is the difficulty of measuring in any quantitative manner the wetting properties when the solid concerned is of a fibrous material.

Any methods which might be applied to study the wetting of cellulose in the form of sheets of regenerated material are open to the objections that the processes of solution and regeneration not only change greatly the specific surface, but probably alter entirely the nature of the surface presented to the liquid.

In attempting to measure the wetting of cellulose possessing the original fibrous structure, the Bartell cell has not yet proved useful due to swelling and the difficulty of uniform packing.

A method is given for evaluating wetting properties by analyzing data on the penetration of liquids into vertical paper strips. The method consists of plotting dh/dT, the rate of penetration, against $1/h$, where h is the distance penetrated. For most liquids a straight line is obtained for values of h from 4 to 12 cm, the slope of which is a measure of the "spreading tension." While certain precautions must be used in the interpretation of results, the application of this method should unfold much desirable information.

The application to dielectric problems is discussed. Besides the effect of the degree of wetting upon the completeness of impregnation, the surface conduction, which is important in studies of conductance and of electrical breakdown in impregnated dielectrics is probably related to the adhesion between the fiber and impregnant due to its effect upon the movements of ions along the surface. The spreading tension may be used as a measure of this adhesion.

Mechanism of Impregnation of Fibrous Dielectrics, G. T. Kohman, Bell Telephone Laboratories, Inc., New York, N. Y.

The process of impregnation of fibrous cellulosic materials with organic impregnating compounds is shown to resemble in many respects the process of absorption of water by cellulose. The latter process has been carefully studied by a large number of investigators, and the information gained, combined with the information concerning the structure of cellulose, has resulted in a fairly complete knowledge of its mechanism.

A mechanism of the impregnation process, based upon the information mentioned above, differing slightly from the water absorption mechanism because of the low vapor pressure of impregnating compounds and large size of the molecules is proposed. According to this mechanism, the degree of wetting of the cellulose by the impregnating compound can be changed by exposing the cellulose to water vapor at a relatively high temperature. Because of the change in degree of wetting brought about by this treatment, penetration of the compound into the fibrous structure is effected, and certain changes in electrical characteristics observed.

The proposed mechanism suggests conditions for the drying of cellulose which are shown to result in increased dielectric strength. It seems probable that it will enable certain variations in electrical characteristics observed by other investigators to be explained.

Capillary Action in Impregnated Paper Insulation, J. B. Whitehead (F'12) and E. W. Greenfield, The Johns Hopkins University, Baltimore, Md.

In the course of a study of the electrical properties of impregnated paper as related to the impregnating process, a series of observations was made of the rate of capillary rise of a number of oils in vertical strips of several types of paper. It was found in every case that the rise was accurately proportional to the square root of the time, over the interval studied, 1 hr to 100 hr.

From the data obtained on 8 different oils and 7 different grades of paper, the following conclusions were drawn:

1. The capillary rise of oil in vertical strips of impregnated paper obeys the same law as the rise of liquids in capillary tubes of circular cross-section.
2. From the viscosity and surface tension of an oil and its rate of rise in a given paper, it is possible to compute the "effective capillary radius" of the capillary pores of the paper. The rate of rise in a calibrated paper affords a convenient means of measuring the surface tension when the viscosity of the liquid is known.
3. The rate of penetration of an oil into a paper is directly proportional to the "penetrativity" of the oil as defined in the theory of capillary action. The penetrativities of 9 insulating oils and the effective capillary radiuses of 7 different papers have been determined.
4. A uniform relationship between the "effective capillary radius" and the Gurley air resistance of the paper is indicated.

These studies have been carried out with the cooperation and support of the underground systems committee of the National Electric Light Association, to whom cordial acknowledgment is hereby made.

IV—Impregnated Paper

Capacitance and Loss in Oil Impregnated Paper, H. H. Race (M'31), General Electric Company, Schenectady, N. Y.

The electrical capacitance and loss characteristics of a single grade of Kraft cable paper were measured as functions of both frequency and temperature before and after impregnation with 2 grades of commercial mineral insulating oil. For the impregnated samples, the temperature range covered was from minus 50 deg C to plus 50 deg C and the frequency range from 60 to 1×10^6 cycles per sec. The data obtained lead to the following conclusions.

1. High frequency losses in paper alone are not caused by conduction in water adsorbed on the fibers since they are not changed by drying the paper.
2. Low frequency losses in undried paper are apparently caused by conduction in water adsorbed on the fibers since they are greatly reduced by drying the paper.
3. High frequency measurements for impregnated paper show relaxation characteristics which change rapidly with temperature as though viscosity of the oil were an important factor. However, the observed losses are much too high to be caused by simple polar orientation in the liquid dielectric and may occur within the fibers where the oil does not penetrate.
4. The losses at low frequencies of oil impregnated paper are higher than either good oil alone or dry paper alone. It seems that the seat of the major portion of the loss lies neither in the oil in the interstices between fibers nor inside the fibers where the oil does not penetrate but may be a surface effect associated with the wetting of the paper fibers by the oil.
5. At decreasing frequencies all loss factor *vs.* frequency curves apparently approach constant values greater than zero. No physical explanation has yet been suggested which will account for such a characteristic. Simple conduction gives an increasing loss factor with decreasing frequency. Any mechanism involving a relaxation time gives a loss factor which approaches zero rather than a definite constant value as the frequency is reduced. Thus the orientation of polar molecules in a viscous medium, the formation of space charges at the electrodes or conduction in restricted paths in a non-homogeneous composite dielectric will not explain observed data unless, as seems highly improbable, 2 or more of these effects combine so that the sum of their losses remains independent of frequency over a fairly wide range. This again leads to the conclusion indicated above that a more comprehensive theory is necessary which shall include interfacial forces between oil and cellulose fibers.

The Dielectric Losses in Impregnated Paper, J. B. Whitehead (F'12), The Johns Hopkins University, Baltimore, Md.

Accurate measurements have been made of the electrical and other physical properties of 10 insulating oils, of a single grade of wood pulp paper, and of the paper when impregnated with each of the oils. Short time charge and discharge curves under continuous potential have thrown further light on the anomalous conduction as found in oils, and permit separation of the dielectric loss into 2 components.

Of the total increase of the loss found in impregnated paper, over the separate losses in oil and in dry paper, one component is proportional to the effective conductivity of the oil. The other component, due to reversible absorption, is for a given paper, a definite function of the free ion content of the oil as indicated by the product of the conductivity by the viscosity. These relations hold over the entire ranges of type of oil and temperature under study. The product of conductivity by viscosity is proposed as a measure of the "electrical purity" of an oil used for impregnation.

The simplicity of the relations shown suggests that an extension of these studies to other grades of paper should make it possible to predict accurately, from the separate properties of paper and oil, the electrical behavior of any grade of paper as impregnated with any type of oil. These results refer to laboratory samples thoroughly impregnated and all showing power factor-voltage curves over the range of study. They therefore represent basic behavior.

The Life of Impregnated Paper as Related to the Impregnating Oil, J. B. Whitehead (F'12), The Johns Hopkins University, Baltimore, Md.

The question of the influence of the basic physical and chemical properties of the impregnating oil on the life of the insulation of high-voltage impregnated-paper-insulated cables has not been satisfactorily answered, nor has it received extensive experimental study. Experiments directed to this question have been conducted using a single type of paper and thoroughly impregnated under identical conditions with 10 different insulating oils, including standard grades of paraffin base, one with an admixture of rosin, and 2 special oils of naphthenic base. In groups of 3 identical specimens the samples were subjected to an accelerated life test at 40 deg C at stresses beginning at 400 volts per mil and rising to 850 volts per mil.

In a separate series of tests reported elsewhere, the capillary properties of each of the oils as regards its penetration into the paper were studied, and the penetrativity of each oil determined. In addition, tests of conductivity, power factor, and loss were made on the oils and on the impregnated specimens at intervals during the life run.

The principal conclusions from the work to date, and which may require modification in the light of future results, are as follows. Great differences are found in the length of life of specimens as impregnated with the various oils, and the oils may be roughly divided into 3 groups:

1. Oils of paraffin base having relatively high viscosity, such as commonly used for the insulation of solid core cables. These oils have low penetrativity and show uniformly very short lives as compared with the other groups.

2. Two thin white oils of very low viscosity, one of which has been used for an oil filled cable, show the longest lives of all the specimens studied.

3. Four specimens of a special naphthenic base oil, all of fairly high viscosity, have shown lives substantially longer than those of the oils of paraffin base within approximately the same range of viscosity.

The following general conclusions are drawn:

1. It is shown that the original or basic chemical structure of the oil has an important bearing on the life of the impregnated paper.

2. The influence of dielectric loss and power factor on the life of impregnated paper is within wide limits negligible compared with other factors.

3. The impregnating properties of the oil as determined by its viscosity and its surface tension have an important influence on the life of the impregnated paper. Measurements of the penetrating power of each oil have been made and it is shown that in general, increased penetrating power results in longer life.

Electronic Devices for Industrial Control

Following the intensive development of electronic tubes in recent years has come an increasing application of these tubes to industrial control operations. Several successful installations in different industries testify to the superiority of this type of control over the more conventional electromechanical type. In this article the relative advantages of electronic control are outlined, and 3 typical applications are described in detail.

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WITH the perfection of the high-current high-vacuum tube with a current carrying capacity as high as 320 ma, and especially after the development of the grid glow tube (gas or mercury vapor filled electronic valve) with a capacity up to 25 amp, the industrial application of electronic tubes was given added impetus. During the last few years much experimenting has been done to adapt electronic equipment to various industrial control and regulating processes.

At the present time, several successful installations in different branches of industry testify to the superiority of electronic control as compared with the conventional electromechanical type of equipment. For this reason, the future field for electronic control devices will be not only to perform functions that cannot be accomplished by electromechanical or other means, but also to supplant electromechanical control and regulating devices, especially where high sensitivity and quick response are required.

Electronic Control Vs. Other Types

In comparing electronic control equipment with other types of control equipment, several features are readily recognized which make the application of electronic devices desirable from an industrial point of view. The outstanding feature of electronic equipment is the high sensitivity that can be attained without the use of sensitively balanced moving parts. As an example may be mentioned voltage regulating equipment. Most electromechanical regulators need dashpots attached to the sensitively balanced lever system to provide damping and to prevent hunting. It is obvious that some friction always will be present in these dashpots; this friction may develop to such an extent as to impair the regulator sensitivity unless the dashpot is maintained in proper operating condition. In electronic regulating equipment the anti-hunting function is accomplished by means of a condenser which operates as a friction-free dashpot, and which does not require maintenance.

The absence of moving parts, and consequently, the absence of mechanical inertia, gives electronic equipment an extremely quick response characteristic. This feature is of utmost importance in many industrial control applications where the impulse initiating the control sequence may have a duration of 0.001 sec or less, as in the control of register in paper cutter applications.

Absence of mechanical inertia makes electronic control ideally suited to applications where the control equipment may be tilted at an angle when operating, for example, voltage regulators on ships. On a vessel that is rolling heavily, minor variations in regulated voltage are likely to occur where electromechanical regulators are used, while electronic type regulators under similar conditions are not affected.

In several industrial control applications, the controlling force, whether mechanical or electrical, may be of such low energy level that its direct application to electromechanical control devices will not give the required sensitivity because of the relatively high amount of energy required to operate such devices. Since the energy required to control an electronic amplifier tube may be as small as 1 μw or even smaller, low-energy-level control problems always can be solved satisfactorily by means of electronic equipment. A particular class of low-energy-level control includes those applications where no contact, either electrical or mechanical, can be made with the quantity under control; in that case, theo-

Based upon "Recent Developments in Electronic Devices for Industrial Control" (No. 33-24) presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23-27, 1933.

Table I—Advantages and Disadvantages of Electromechanical Time Delay Relays

Type of Relay	Advantages	Disadvantages
Relay with dashpot	Simplicity	Maximum time delay approximately 10 sec. Time delay is dependent upon the supply voltage. Time delay is affected by temperature changes caused by variations in dashpot damping. Friction may develop in the dashpot with consequent change in time delay. Instantaneous reset cannot be obtained without mechanical complications
Escapement relay	No temperature error Instantaneous reset	Relay is subject to mechanical wear, and is noisy. Time delay is limited to approximately 10 sec
Motor operated gear train relay	Time delay adjustable from 30 sec to 4 min	Expensive. Mechanically complicated
Flux decay type relay	Instantaneous reset Inexpensive	Requires direct current for operation. Maximum time delay 8 sec
Thermal relays	Inexpensive	Not very accurate. No instantaneous reset

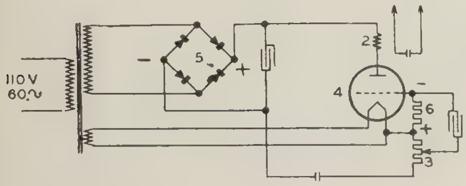


Fig. 1. Schematic diagram of electronic time delay relay

retically, the energy level is 0. In such applications, however, positive control frequently can be accomplished by means of a light beam, a photoelectric cell, and associated amplifying equipment.

Among other desirable features of electronic control may be pointed out the small amount of maintenance required to keep the equipment in proper operating condition. There are no moving parts to be oiled and adjusted for wear and no contacts to be filed to remove the effects of arcing, as in electro mechanical control devices. The only maintenance required on a properly designed electronic control device is the replacement of tubes at the end of the useful tube life—an operation which can be accomplished in a few seconds. Another feature of electronic control which may be considered a desirable one in certain applications is its freedom from noise. In this connection also should be mentioned the absence of radio interference with most types of electronic equipment. A typical example is the electronic voltage regulator for d-c generators, as compared with the vibrating type. The problem of radio interference in connection with d-c control equipment is being given serious consideration.

Because the energy required to control electronic devices is so small, manual control can be accomplished by means of small radio type potentiometers only about $1^1/_2$ in. in diameter. This makes it possible to design compact miniature control panels for various types of process control; if desirable the complete control unit may be built into a portable box arranged with a plug for connection to control receptacles located at various strategic points.

There are 2 other features of electronic control equipment which must be considered in order to get a true picture of the relative merit of this type of control: one is the apparent fragility of the electronic tubes; the other is the necessity of occasional tube replacement. Experience with various types of electronic applications indicates, however, that the possibility of tube breakage is rather remote provided reasonable care is exercised in handling the tubes. The life of electronic tubes, at rated current varies between 2,000 and 5,000 operating hours for grid glow tubes, and between 3,500 and 10,000 operating hours for high-vacuum tubes. By operating the tubes at less than rated current, considerably increased life is obtained. As previously mentioned, replacement of tubes can be accomplished in a few seconds; from a continuity of service point of view, therefore, the necessity of tube replacement is no serious drawback.

In deciding whether to use electronic control equipment or electromechanical or other types of equipment in any particular installation, the yearly savings from improved operation should be credited to the electronic side, and the yearly cost of tube replacement should be balanced against the decreased maintenance cost. In many industrial installations it will be found that the cost of tube replacement is insignificant compared with the increased profits resulting from the greater uniformity of the product and the consequent decrease in percentage rejections.

To demonstrate some of the points brought out in the foregoing discussion, a few typical examples of electronic control now will be described in detail.

Electronic Time Delay Relays

The combination of an electronic tube and a condenser discharge circuit provides the fundamental circuit for a time delay relay that has all of the desirable features of the various types of electromechanical relays now on the market, but none of the less desirable features of those devices.

Electromechanical time delay relays may be classified in 5 different groups according to the principle of operation, as in Table I. The electronic time delay relay, the circuit of which is shown in Fig. 1, has all of the desirable features of the electromechanical relays, and does not have any of the undesirable characteristics.

Referring to Fig. 1, a high vacuum amplifier tube 4 is connected in series with a relay 2 and a potentiometer 3 across the d-c output terminals of a copper oxide rectifier 5. When the initiating contacts 1 close, plate voltage is applied to tube 4, and the current through the coil of relay 2 and through potentiometer 3 starts to build up. The resulting increasing voltage drop across potentiometer 3 will cause a charging current to flow through resistor 6 to condenser 7. This charging current will produce a voltage drop across resistor 6 with polarity as shown. This voltage drop will give the grid of tube 4 a negative bias in relation to the cathode, and for this reason the rate of change of current through tube 4, and consequently through relay 2, will increase slowly. After a predetermined time, dependent upon the adjustment of potentiometer 3, the current through relay 2 will be high enough to operate the relay. The time interval between closure of contacts 1 and operation of relay 2 may be adjusted from 0 to maxi-

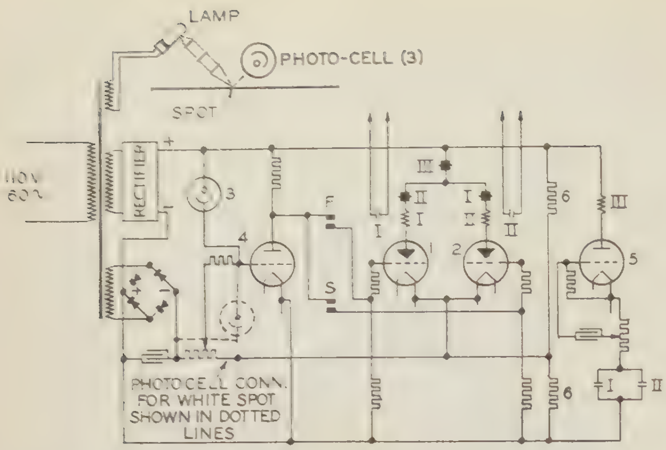


Fig. 2. Schematic diagram of electronic register control equipment

mum by adjusting the movable contact of potentiometer 3.

The maximum time delay obtainable with the electronic relay is proportional to the product RC, where R is the resistance of resistor 6 in ohms, and C is the capacity of condenser 7 in farads. By adjusting potentiometer 3 any value of time delay between 0 and maximum may be obtained. In order to obtain sufficient sensitivity in time delay adjustment, various values of resistor 6 should be used for different time delay ranges. Since resistor 6 is a small grid leak type resistor, the adaptation of the relay to various time delay ranges can be accomplished easily. The maximum time delay of this equipment is approximately 3 min, the minimum 0.05 sec. The time delay for any definite adjustment of potentiometer 3 remains constant within ± 5 per cent. The equipment operates from a 110-volt 60-cycle source, and requires approximately 10 va for its operation. The time delay does not vary more than 1 per cent for changes in the a-c supply voltage within the commercial range of ± 5 per cent.

Where frequent adjustment of the time delay is required, the electronic time delay relay is particularly suitable. A typical application of this nature is found in spot welding, where a relay circuit as shown in Fig. 1 meets the desired requirements of accuracy and adjustability.

Register Control

In various industrial processes it is required to synchronize or register 2 separate control operations so that space and time relationship between the 2 remains constant. To illustrate this type of application, the problem of maintaining the register of the knife in paper cutting will be outlined. In continuous cutting the material is fed to the cutter from a reel by means of a pair of draw rolls. The cutter is usually of the rotating type and is driven from the same motor as the draw rolls. If there is a printed design on the material, it is desirable to maintain the register of the cut in relation to the printed design. This is obtained either by adjusting permanently the speed of the draw rolls in relation to the cutter

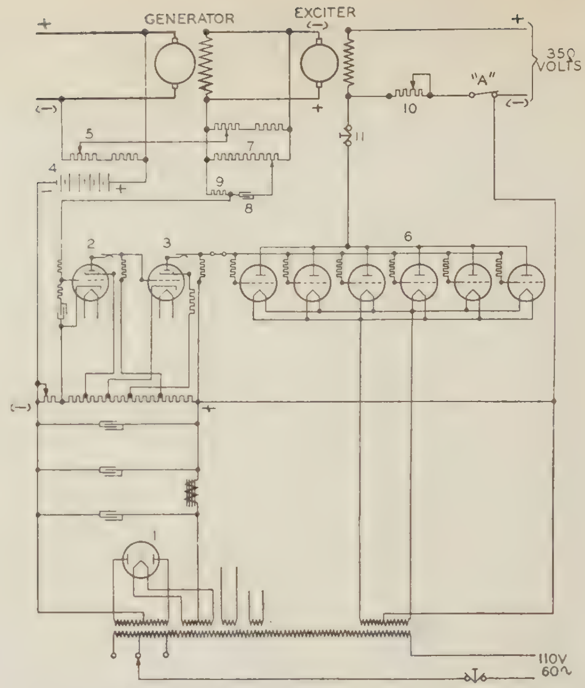


Fig. 3. Schematic diagram of an electronic voltage regulator for d-c machines

speed, or by changing the draw roll speed temporarily. In the latter case the adjustment is equivalent to a space correction of the material to be cut, in relation to the cutter knife.

Present paper cutters usually require 3 operators for successful operation. One of the operators is kept continuously busy regulating the speed of the draw rolls, another stacks the paper when it leaves the cutter, and the third sorts the sheets and arranges for further trimming those sheets that have been cut incorrectly. The work of the operator regulating the draw roll speed is exceedingly monotonous, and from time to time he will find the knife cutting the paper considerably off the printed spot used for indicating the proper position of the cut. This results in considerable waste of paper and expense in trimming the sheets to their proper length. By applying photoelectric control of the draw rolls the amount of wasted paper, which at present may be up to 15 per cent or more, will be reduced considerably, while the number of operators usually can be reduced from 3 to 2.

The photoelectric paper register control device operates on the general principle of synchronizing a spot printed on the paper with a pair of cams attached to the rotary cutter shaft. When the cut is in register the contacts operated by the rotating cams do not engage when the photoelectric cell impulse is obtained. For this reason no relay action takes place. If however, the cut is either slightly ahead of the spot or behind it, one pair of contacts will engage at the instant of photoelectric cell impulse; by means of suitable amplifying equipment a control relay will be closed which will operate the draw roll speed adjuster or position adjuster to bring the paper back in register with the knife.

In some cutters the slip of the paper in relation to the draw rolls either is 0 or is practically constant so

that when the speed ratio between cutter and draw rolls once is adjusted the entire control can be obtained by means of position control. In other cutters the slip varies considerably because of changing paper characteristics; under these conditions a speed ratio change as well as a position change is required for satisfactory operation.

In Fig. 2 is shown an elementary diagram of an electronic register control device which will operate either from an impulse received from a white, yellow, or red spot on a dark background, or from a dark spot on a white, yellow, or red background. The equipment may be arranged to operate with transmitted light when the transparency of the paper is high, or with reflected light when the paper is opaque. A photoelectric cell 3 is connected to control amplifier tube 4 so that when the spot intercepts the beam of light the current through the amplifier tube will decrease. Grid glow tubes 1 and 2 are connected in series with their respective relays I and II; by means of voltage divider 6 the grids of these are given a definite negative bias in relation to the cathodes so that normally they will not carry current. Contacts F and S are operated by the cams connected to the rotating cutter knife; they are adjusted so as to be open when the spot intercepts the light beam if the cutter knife is in register. If the draw rolls are operating too fast contacts F will be closed at the instant of photoelectric cell impulse; consequently, since the current of tube 4 has been decreased by the action of the photoelectric cell, a positive bias will be impressed on the grid of tube 1, thus causing that tube to break down and energize relay I. Relay I energizes a motor which operates the stationary element of a mechanical differential connected between the driving motor and the draw rolls, so that the draw roll speed will be reduced an amount equal to the output speed of the mechanical differential. Since the grid glow tubes are energized from a d-c source, relay I will remain closed until the plate circuit of tube 1 is opened by relay III; relay III is controlled by tube 5 which is connected in a time delay circuit similar to that of Fig. 1. If the paper is lagging in relation to the cutter knife, contacts S will be closed when the photoelectric cell impulse occurs and relay II will close to operate the mechanical differential in the reverse direction.

By the use of grid glow tubes the response of this equipment is practically instantaneous so that a sensitivity of $^1/_{16}$ in. can be obtained with a spot $^1/_8$ in. wide for paper speeds in excess of 500 ft per min. The equipment operates from a 110-volt 60-cycle source, and the performance is not affected by voltage changes within $\pm$ 5 per cent. The equipment can be applied advantageously to a variety of cutter installations, but is not limited to that field alone.

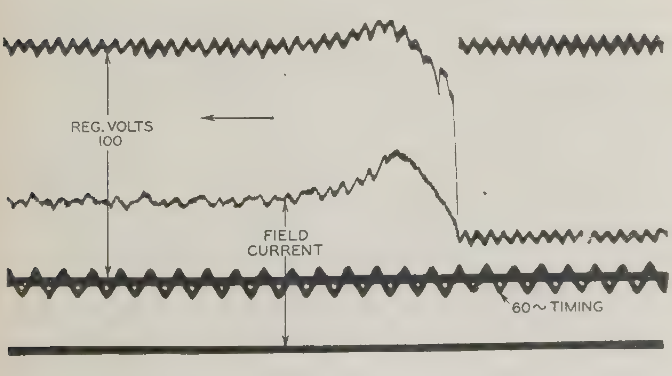
A Voltage Regulator for D-C Machines

Because of unavoidable friction in dashpots, bearings, and other moving parts, the various electromechanical voltage regulators now on the market have a definite insensitivity zone. By proper design and through careful maintenance, however, the regulator sensitivity can be kept within a zone of $\pm$ 0.5 to 1 per cent, which is entirely satisfactory for most industrial applications. The response of the average industrial regulator usually is not considered to be of much consequence unless lights are connected to the circuits; but there are applications, for example in motion picture studios, where this feature is of paramount importance. The speed of response of electromechanical voltage regulators is limited by the inertia of levers and other moving parts of the device, and, not considering the rheostatic type regulators, the speed of response also is limited by the inherent characteristic of the antihunting mechanism.

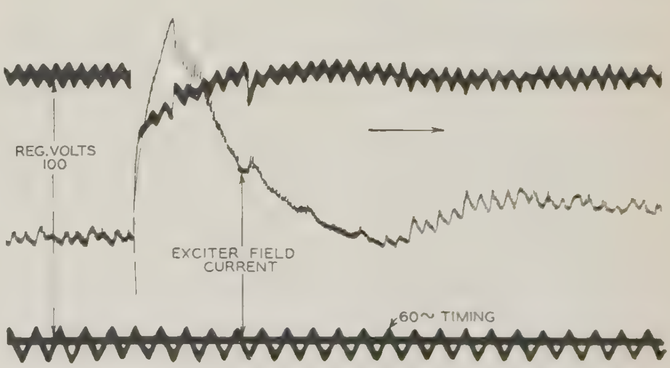
Antihunting is required in any voltage regulating device because of the electrical inertia of the exciter and generator; the success of a voltage regulator depends to a large extent upon the proper selection of the antihunting means. Through the antihunting means a corrective force, either electrical or mechanical, is applied to the primary element of the voltage regulator during the regulating period to counteract the corrective regulator action, so that at all times the rate of voltage correction is proportional to the error in voltage.

An electronic voltage regulator for d-c generators that embodies ideal antihunting characteristics recently has been developed. Exhaustive tests indicate that in respect to sensitivity and response this regulator is superior to any electromechanical voltage regulator previously available.

A schematic diagram of the electronic voltage regulator is shown in Fig. 3. The regulated voltage



Regulator connected directly to the generator field



Regulator connected to the field of a $^1/_2$-kw exciter which was connected to the generator field

Figs. 4 and 5. Response of electronic voltage regulator as full load was applied to a 5-kw d-c generator

obtained from potentiometer 5 is bucked against the constant voltage from battery 4, and the voltage difference is applied to the grid of screen grid tube 2. The regulator, when in operation, will tend to maintain this voltage difference constant at 1.7 volts. Any deviation in this voltage difference is amplified by tube 3 and power tubes 6 so that a minute change in regulated voltage will cause a comparatively large change in the current in the exciter field, the winding of which is connected in series with the power tubes across a 350-volt of d-c source. To prevent hunting, resistor 9 is connected in series with condenser 8 across potentiometer 7 which is connected to the exciter armature terminals. When the exciter armature voltage is decreasing as a result of regulator action when load is disconnected from the generator, condenser 8 will discharge through resistor 9; the resulting voltage drop will oppose the initial voltage change on the grid of tube 2 caused by the increase in regulated voltage, and thus will stabilize the regulator operation.

Sensitivity of the electronic regulator is $\pm$ 0.2 volt or better, and if the exciter is omitted and the power tubes are connected directly in series with the generator field winding, the regulator will bring the regulated voltage back to normal in from 2 to 5 cycles as indicated by the oscillogram in Fig. 4; during this test full load was connected to a 5-kw shunt wound generator. In Fig. 5 is shown an oscillogram for the same load conditions, with a $^1/_2$-kw shunt wound exciter used to supply the excitation for the generator. The speed of response of the regulator is apparent from Fig. 4 which indicates that the regulator tends to correct for variations in regulated voltage due to commutator ripples, these being rather pronounced on that particular generator. The action of the antihunting circuit is indicated in Fig. 5 from which it may be seen that the exciter field current starts to decrease before the regulated voltage has reached its normal value.

To transfer from automatic to manual control (see Fig. 3) rheostat 10 is turned in and switch A is closed. The rheostat then is turned out gradually until the regulated voltage is 0.5 volt higher than normal, thus indicating that the current through the power tubes is zero. Field switch 11 now may be opened and manual control obtained by means of rheostat 10.

The regulating range of the 6 tubes used in the circuit of Fig. 3 when new is 0.15 amp to 1.2 amp; however, at the end of the useful tube life the filament emission will be decreased slightly, and for this reason the regulator is applied on the basis of a maximum current of 0.9 amp, thus giving a regulating range of 0.75 amp. If the maximum exciter field current exceeds 0.9 amp, switch A is not supplied, rheostat 10 is connected permanently in parallel with the power tubes, and is designed to carry the no load exciter field current minus the minimum tube current 0.15 amp. With this arrangement the electronic regulator may be applied to control exciters up to approximately 20 kw capacity, which is sufficient for most industrial d-c generators.

Besides its use for voltage control, the electronic regulator has been applied successfully as a speed regulator for a single motor paper machine drive. In this case the motor was connected for armature control by means of a variable voltage generator; the regulator was connected in the field circuit of the exciter which supplied excitation for the generator. A pilot generator geared to the motor served as the voltage indicator.

Other Applications

In addition to the electronic voltage control equipment just described, an electronic motor starter has been developed by means of which a d-c motor may be operated over a wide range of speed direct from an a-c source. This device utilizes a phase shift controlled grid glow power tube, and is adapted particularly well to applications where frequent speed adjustments are required and where a smooth starting characteristic is of importance.

Another type of electronic control which is finding increased application to industrial processes, is the use of the photoelectric cell with associated electronic equipment for counting, sorting, and inspection. Often the use of photoelectric equipment offers the only solution for a successful installation if the objects to be counted, sorted, or inspected are fragile and non-metallic. Photoelectric equipment also has been widely applied to initiate control operations where mechanical indicating means would not have been adequate. However, space limitations will not permit more than a mere mention of this equipment.

Examples given in this article obviously do not cover the entire range of possibilities for profitable application of electronic control equipment in the industrial field; an endeavor has been made merely to point out the characteristic applications of this equipment, in order to show its universal adaptability to almost any control problem that the industrial engineer may face.

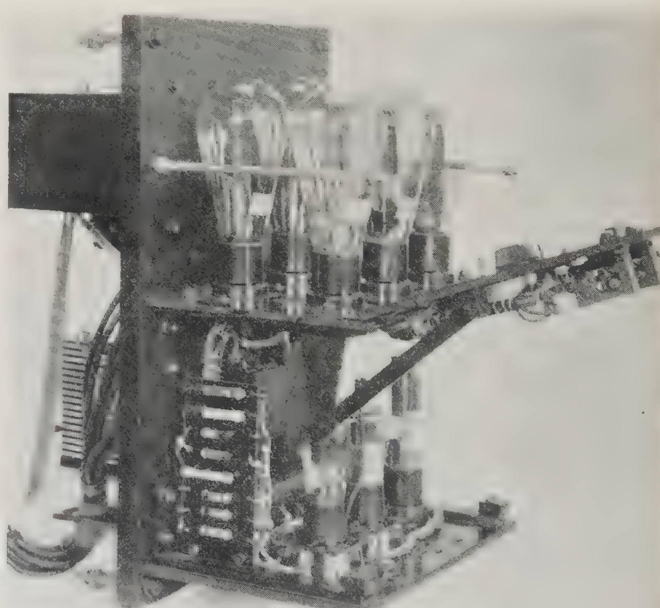


Fig. 6. Electronic voltage regulator with covers removed. Note compact arrangement of parts

Power Supply for the Pennsylvania Railroad

An energy consumption of 238,000,000 kwhr per year will be required to handle through passenger trains on the electrified portion of the Pennsylvania Railroad system between New York City and Philadelphia, Pa., on which through service recently was initiated. This article describes the system used to supply that energy to the moving trains. The arrangement of apparatus and circuits adopted has resulted in low first cost, low operating maintenance, and reliability and simplicity of operation.

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PASSENGER SERVICE on the Pennsylvania Railroad's electrified line between New York City and Philadelphia, Pa., in normal times consists of 236 trains daily. To handle this traffic electrically will require the yearly consumption of 238,000,000 kwhr of electric energy. In addition to this, 96,000,000 kwhr per year will be required to operate the Philadelphia suburban service to Paoli and Chestnut Hill, Wilmington, West Chester, Norristown, and Trenton, where 345 multiple unit cars are now in use, and 11,000,000 kwhr more per year will be required to operate the suburban service between Jersey City and New Brunswick, N. J., where 40 multiple unit cars soon will be placed in service. When electrical operation through freight train service between the eastern terminals and the south is begun at some later date, an additional yearly supply between New York and Philadelphia of 137,000,000 kwhr will be required.

Thus, under normal traffic conditions, the handling of through passenger trains between New York and Philadelphia will require an energy consumption of approximately 2,640,000 kwhr per year per route mile of railroad. If to this figure is added the energy required for the operation of suburban trains, 4,730,000 kwhr per year per route mile of railroad will be required in the heaviest suburban area; and when the through freight load is added at a later date, this figure will be increased to 6,290,000 kwhr per year per route mile of railroad. (See Fig. 2.)

To handle these loads adequately, there has been provided an initial installation of 1,280 kva of step-down transformers per route mile of railroad with provisions in the design for increasing this capacity to 2,025 kva to whatever extent and as rapidly as conditions indicate to be necessary.

Power Supply Sources

To supply the large quantity of energy required the railroad company had available, when the through electrification was decided upon, 2 sources of single phase current, one of which was the Long Island City power plant at New York. This plant was built in 1905 for the supply of current to the Long Island Railroad electrification and had been extended and improved from time to time, and the turbine-generators replaced by larger machines suitable for generating either single-phase or 3-phase current. The plant, therefore, was suitable for supplying current to the New York end of the through electrification.

The second available source of single phase current was at Philadelphia, where a contract had been made with the Philadelphia Electric Company in 1915 when the Paoli electrification was placed in service. This contract had been supplemented from time to time to take care of the additional current supply needed for the Chestnut Hill, Wilmington, West Chester, Norristown, and Trenton electrifications,

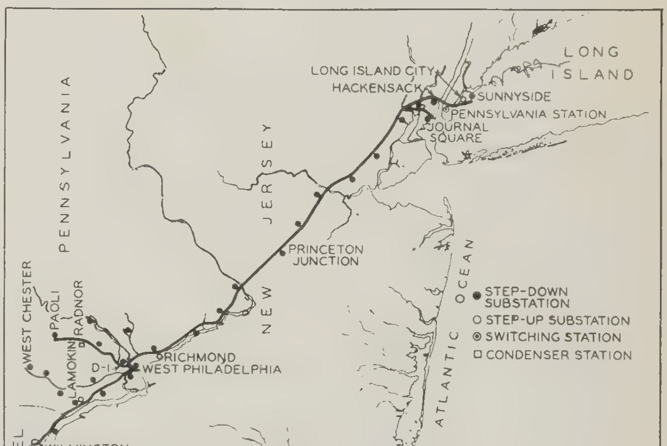

Fig. 1. Map of the electrified portion of the Pennsylvania Railroad system showing location of substations

and it afforded a logical means for the railroad company to secure single phase current for the Philadelphia supply of its through electrification to New York. It was necessary, however, to supplement the single phase generating equipment of the Philadelphia Electric Company; this was done by installing a frequency changer station at that company's Richmond plant, at which point the railroad company erected a step-up transformer station, to operate in conjunction with the other power supply points in Philadelphia.

Full text of a paper presented before the transportation group of the A.I.E.E. New York Section, New York, N. Y., Jan. 11, 1933. *Not published in pamphlet form.*

In view of the importance of this service, it was felt that an additional source of power supply should be available between Philadelphia and New York for use in case of necessity; accordingly, a contract was entered into for an emergency source of power from the Public Service Electric & Gas Company of New Jersey. A combined frequency converter and step-

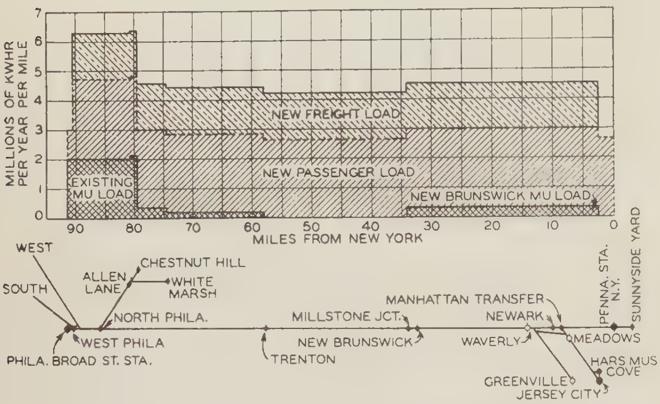

Fig. 2. Chart showing energy consumption between New York City and Philadelphia

up station will be built by the railroad and power companies for the supply of emergency power to the railroad, as well as for synchronous condenser operation for improving voltage regulation when desirable.

Current furnished from the single phase generators at the Long Island City power station is supplied at 11-kv to a single phase bus and one-to-one ratio transformers at Long Island City, and from these transformers through suitable oil circuit breakers to concentric cables leading to the Hackensack (N. J.), portal, the western opening of the railroad company's tunnels under the North River (see Fig. 3). At this point, suitable oil switches and step-up transformers connect the concentric cables to 4 132-kv transmission circuits leading to Philadelphia. At Philadelphia, these circuits are connected to the present transmission system of the single phase electrification.

Sources of power supply in Philadelphia are 2 in number: the newly installed frequency changer station at the Richmond Street plant of the Philadelphia Electric Company (see Fig. 4); and the existing Lamokin Street frequency changer station of that company at Chester, Pa. Each of these stations supplies current to a step-up transformer station of the railroad company, which in turn supplies the 132-kv transmission system of the railroad company.

Arrangement of Distribution System

With this description of the sources of power, we may pass to the system designed to distribute this power to the electrically operated trains. Economy of first cost and operating maintenance, as well as reliability of operation and simplicity of detail, were leading points receiving consideration in this design.

At the frequency changer stations of the power company 25-cycle single-phase 13-kv power is delivered to the bus of the railroad company. From this bus, it is passed through suitable oil circuit breakers to the 13-kv windings of the step-up transformers. At the Lamokin Street station, these transformers are 4 in number and are of 15,000-kva capacity each. At Richmond Street, the initial installation of transformers is 6 and each transformer is of 20,000-kva capacity. From the high voltage windings of these transformers, the current passes through motor operated air break disconnecting switches, remotely controlled but non-automatic except for transformer faults, to the 4 132-kv transmission circuits, which are carried on the same poles that support the catenary and trolley wires.

At intervals of approximately 7 to 10 miles the 132-kv transmission circuits are connected to step-down transformer stations located along the railroad. Connection between the transmission circuits and the step-down transformers is by means of remotely controlled motor operated air break disconnecting switches, non-automatic except for transformer faults. The transmission circuits are sectionalized by air break disconnecting switches, motor operated, remotely controlled, non-automatic, at each side of each substation. These switches are arranged so that either one of 2 of the 132-kv circuits may be connected to one 4,500-kva step-down transformer; either one of the other 2 132-kv circuits may be connected to the second 4,500-kva step-down transformer. The substations are designed so that 2 additional, 4,500 kva step-down transformers may be added; each 132-kv transmission circuit then will connect to one 4,500 kva step-down transformer,

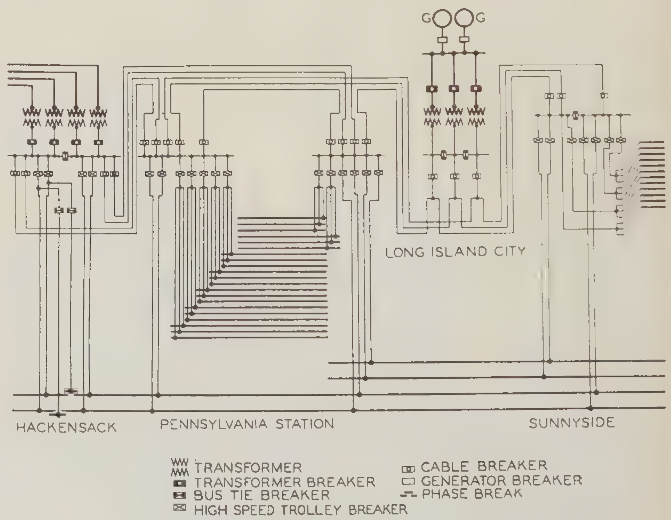

Fig. 3. Schematic diagram of the power supply system in the New York City area

thus providing one transformer per transmission circuit at each substation. This arrangement is shown in more detail in Fig. 5.

From the low voltage (11-kv) side of the step-down transformers, current is passed through oil circuit breakers to an 11-kv trolley bus. These breakers are automatic for differential and overload protection to the transformers, for transmission line short circuits or grounds or trolley bus grounds. The trolley

bus is sectionalized into 2 parts connected by an oil circuit breaker which is non-automatic except for bus short circuits or grounds.

From the 11-kv trolley bus, current passes through quick acting circuit breakers to the trolleys. There are 10 of these circuit breakers in each substation: 4 feed the trolleys at one side of the station from one section of the bus, and 4 feed the trolleys on the other side of the station from the other section of the bus; 2 feed the trolleys over the crossovers between the different tracks, the substations being located at interlockings for easy control from the tower which controls the interlocking.

Operation of System

Arrangement of 132-kv circuits, step-down transformers, low voltage breakers and trolley circuit breakers, together with the controlling relay system, is such that a short circuit on any trolley is opened by the quick acting trolley breakers at the substations feeding such trolley, without affecting the other trolley circuits, the transformers, or 132-kv circuits.

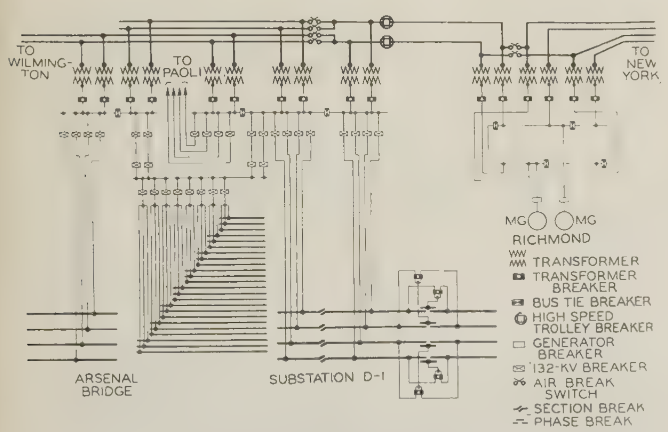

Fig. 4. Schematic diagram of the power supply system in the Philadelphia area

A bus short circuit or ground is opened without interfering with the trolleys on the other section of the bus, the transformers, or high voltage circuits. Trouble in a transformer disconnects it without interfering with the trolley bus, but takes out the transmission line to which the transformer is connected. After this has taken place, the disconnecting switches between the transmission line and the transformer will open automatically. The transformer then will be segregated and the transmission line can be reenergized.

A transmission line short circuit or ground opens the low voltage transformer breakers at the step-up substations on the line in trouble, as well as the low voltage transformer breakers at each step-down substation on the transformers connected to such transmission line. If the short circuit or ground does not clear itself immediately, the line must be sectionalized and the transformers switched over to the other transmission line. Owing to the reliability of operation of the 132-kv transmission circuits, it has been found that little trouble of this character is experienced and that the transmission arrangement as a whole works satisfactorily. It has been in operation on the Wilmington and West Chester electrifications for 4 years and has, therefore, been continued for our through electrifications between New York and Philadelphia.

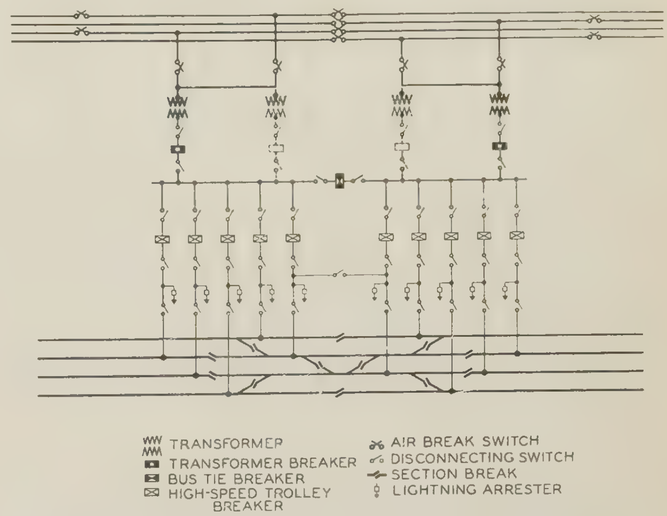

Fig. 5. Schematic diagram of a typical substation; these are located at intervals of from 7 to 10 miles along the railroad

Advantages of System Summarized

Many outstanding advantages in the way of low first cost, low operating maintenance, reliability, and simplicity of operation result from the arrangement of circuits and apparatus used. In general, these advantages may be summed up as follows:

1. Selection of 132 kv as a transmission voltage permits the placing of these circuits on the catenary poles, produces the maximum economy of transmission line construction cost with a minimum of expenditure for property and electrical construction, and permits the efficient movement of practically any desired quantities of electrical energy to any point in the electrified territory.

2. Use of air break disconnecting switches in the 132-kv circuits in place of oil circuit breakers reduces the first cost of the transmission line and substation construction, considerably reduces maintenance costs, and simplifies the layout of the system. It is believed to increase the reliability of operation by simplifying the details of construction and reducing the number of pieces of apparatus used.

3. Use of quick acting circuit breakers in the trolley circuits permits the rapid selection and elimination of a fault in any of these circuits, or in any locomotive or car transformer connected thereto, with minimum disturbance to the other circuits of the system and minimum damage to the circuit or apparatus upon which the fault occurs. The use of air circuit breakers in these circuits permits the elimination of oil, reduces maintenance costs, and increases the reliability of the circuit because of the reduction in number of parts and the simplification of apparatus.

4. Utilization of transformers of the "inertaire" type, or of the conservator type, or equivalent construction, has greatly reduced possibility of transformer failure, and has practically eliminated the necessity of facilities for handling transformer oil in the substations.

5. The decision not to use 132-kv lightning arresters was made after a careful study and coordination of the insulation of the line, transformer bushings, oil switch bushings, and transformer windings, including the placing of ground wires on the transmission poles and lightning rods on the steel structures of the substations. This decision has reduced the first cost of the line, and the maintenance of the line and substations; it has increased the reliability of the

system by the elimination of unnecessary parts and is expected to result in a high order of operating reliability.

6. Use of lightning arresters on the 11-kv trolley circuits protects both these circuits and the car and locomotive equipment.

Catenary System

No description of the power supply system of a railway electrification would be complete without some mention of that portion of the system which supplies the current from the stationary substation to the moving vehicle on the tracks. It is one of the most important features of an electrification and one to which the most careful thought must be given. Its design involves many of the most important details of transmission line design, as well as many other problems, one of which is to secure proper transfer of current from a static wire to a rapidly moving vehicle on a track beneath this wire.

Some of the details of construction of the contact system that must be adequately taken care of are as follows:

1. The contact wire must be smooth and flexible.
2. Height above the track and tension of the conductors must vary as little as possible with variations in temperature.
3. Wind pressures must not displace the system to a point where this displacement will interfere with the proper contact with the pantograph on the moving vehicle.
4. The system must be designed so as to require as little maintenance as possible, because any maintenance work necessarily must interfere with train movements.
5. Where the construction must be lowered to pass under overhead bridges or other obstructions, the grades must be smooth and gradual and the changes in grade must be even.
6. Where the construction is supported under low overhead structures, flexibility of support must be secured to obtain sparkless collection of current.
7. Where trains pass from one supply circuit to another, section breaks in the trolley construction are used. These section breaks must permit smooth passage of the pantograph from one circuit to the other without interruption of current supply to the train, and at the same time connect the 2 circuits together only during the passage of the pantograph.
8. Where different sources of power supply are used, and where these power supplies may be operated either in parallel or separately, provisions must be made in the trolley construction to permit pantographs to move from one source of supply to another without interrupting the supply of current to the train, or with as little interruption as possible. These "phase breaks" are designed so that under normal conditions there is no interruption of current to the train and, when the power supplies are not operating in parallel, the interruption to the train is for a short distance only.

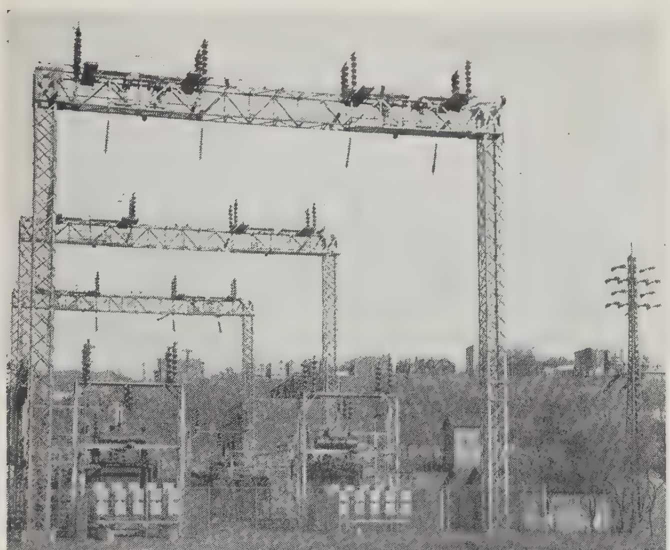

Fig. 6. Substation at Hackensack portal, the western end of the tunnel under the North River into New York City

To meet these conditions, the Pennsylvania Railroad has adopted the inclined catenary system of construction. A bronze messenger wire is suspended in a catenary curve over each track; beneath it in a horizontal plane is supported, by hangers of different lengths, a grooved copper auxiliary wire. Under this is clipped at intervals a grooved bronze contact wire upon which the pantograph shoe moves. All parts of this construction are of noncorrosive or heavily galvanized material riveted

Fig. 7. Typical 4-track electrical construction; note that the trolley circuits, signal circuits, and communication circuits are carried on the same structures that support the 4 132-kv single-phase transmission lines

together to prevent interruptions to service due to loosened nuts or clips.

Distribution Circuits on Locomotives

Locomotives and multiple unit cars are equipped with pantographs, designed so as to follow closely the surface of the contact wire at all speeds. These pantographs are light in weight, quick in action, and operate at uniform pressures over heights varying from 15 ft 3 in. above track rail to 25 ft. When it is realized that the locomotives handling through passenger trains have a starting tractive effort of 56,000 lb and a continuous rating of 3,750 hp, and

that the electrical energy representing these values must be delivered from a wire approximating the size of a man's finger to a flat surface about 8 in. wide, either at rest or when passing along this wire at a speed of 70 mph, the difficulty in securing satisfactory operation may be understood.

With the transformer capacity required by the locomotive design and with the generator and line capacity available in the supply system, the installation of an adequate circuit breaker in the restricted confines of a locomotive cab is difficult. Therefore, a relay is used, which, in the event of trouble, successively disconnects portions of the secondary circuits until the trouble is cleared. If the trouble cannot be cleared in this manner, or if it is in the high voltage winding of the transformer, the relay closes a ground switch on the locomotive roof which causes the substation trolley breakers to open.

The no-voltage condition thus produced on the trolley wire permits the relay to operate still further to lower the pantograph of the locomotive. This clears the trouble from the line and permits the substation breakers to be reclosed. This use of the substation breakers to select and disconnect faulty electrical equipment on locomotives and cars is one of the many steps taken to reduce the number of parts and increase the reliability of the power supply system.

It would be possible to continue this description of the electric power system to include the negative returns between the locomotive and the substation negative bus. The many interesting features of these negative returns, the coordination of the different types of current utilizing them, and the proper design of the returns to provide adequately for the separation and control of these currents, would constitute an article in themselves and therefore no attempt will be made to go into them in this article.

Impedance Curves of a Composite Cable

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The balancing of a composite submarine telegraph cable, that is, one composed of both loaded and unloaded sections, requires a knowledge of its terminal impedance characteristics. In this article the impedance of such a cable is shown to be similar to that of an "equivalent" unloaded cable. Because of its limited frequency range, however, the type of network used with the unloaded cable at low speed signalling cannot furnish a satisfactory balance at the higher speeds of which the composite cable is capable; it is predicted that the mathematical theory developed here will aid in devising a means of extending that range.

SOLUTION of the problem of balancing a composite cable is the object of the following study. Since the balancing of a cable consists in finding a network that will have at all frequencies within a sufficiently wide frequency interval the same terminal resistance and reactance as the cable, it is obvious that the character of the terminal resistance and reactance curves of the composite cable must be studied before a constructive method can be devised which will lead to a satisfactory balancing network. Hence the first part of this study is devoted to a mathematical analysis of the terminal impedance of a composite cable.

Figure 1 represents diagrammatically a composite cable. Its terminal ends of length l are free from inductive loading and in the section between these unloaded terminal ends the cable is loaded with uniformly distributed inductance. The loaded part is indicated in this diagram by the heavy line.

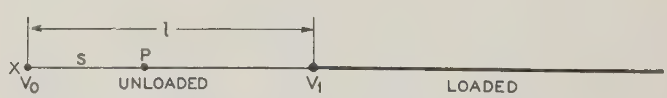

Fig. 1. Schematic diagram of a composite cable

Let V_0 = voltage impressed at the unloaded terminal X, Fig. 1, then the voltage V of any point P which is s nautical miles from this terminal is given by

$$V = V_0 \cos ks + B \sin ks \quad (1)$$

$$\text{Where } -k^2 = -(\alpha - j\beta)^2 = jpC(jpL + R) \quad (2)$$

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L, R, and C are the inductance, resistance, and capacity per nautical mile of the unloaded part of the cable, the "primary" of the composite cable. The current I is given by the equation

$$I = \frac{jpC}{k}\left(-V_0 \sin ks + B \cos ks\right)$$

Let $I = I_0$ when $s = 0$

$$\text{then } I_0 = \frac{jpC}{k} B \quad \text{or} \quad I = -\frac{jpCV_0}{k} \sin ks + I_0 \cos ks$$

$$I_l = \frac{-jpCV_0}{k} \sin kl + I_0 \cos kl = \frac{V_l}{a_1 - jb_1}$$

$$= \frac{1}{a_1 - jb_1}\left(V_0 \cos kl + \frac{k \sin kl}{jpC} I_0\right) \qquad \textbf{(2a)}$$

where I_l is the current and V_l is the voltage at distance l, and a_1, b_1 are the terminal resistance and reactance, respectively, of the loaded part of the cable. From eq 2a follows:

$$V_0\left(\frac{\cos kl}{a_1 - jb_1} + \frac{jpC \sin kl}{k}\right) = I_0\left[\cos kl - \frac{k \sin kl}{jpC(a_1 - jb_1)}\right]$$

$$\text{or } V_0\left(\frac{jpC \sin kl}{k \cos kl} + \frac{1}{a_1 - jb_1}\right) = I_0\left[1 - \frac{k \sin kl}{(a_1 - jb_1)jpC \cos kl}\right] \qquad (3)$$

$$\text{Let } \frac{jpC \sin kl}{k \cos kl} = A_1$$

$$\text{and } \frac{k \sin kl}{jpC \cos kl} = B_1$$

Then

$$\frac{B_1}{A_1} = \frac{k^2}{(jpC)^2} = -\left(\frac{jpL + R}{jpC}\right) = -(a - jb)^2$$

where a and b are the terminal resistance and reactance, respectively, of the unloaded cable when it is considered to be infinitely long. Hence

$$V_0\left[A_1 + \frac{1}{a_1 - jb_1}\right] = I_0\left[1 + \frac{A_1(a - jb)^2}{(a_1 - jb_1)}\right]$$

$$\text{When } A_1 = \frac{1}{a - jb} = \frac{1}{\sqrt{\dfrac{jpL + R}{jpC}}}$$

$$\text{then } \frac{[(a_1 - jb_1) + (a - jb)]V_0}{(a_1 - jb_1)(a - jb)} = I_0\left[\frac{a_1 - jb_1 + a - jb}{a_1 - jb_1}\right]$$

Therefore $I_0 = \dfrac{V_0}{a - jb}$ as it ought to be.

For lower frequencies A_1 is not equal to $\dfrac{1}{a - jb}$

$$\text{Hence } I_0 = \left[\frac{A_1(a_1 - jb_1) + 1}{a_1 - jb_1 + A_1(a - jb)^2}\right] V_0$$

$$\text{Since } \frac{jk}{jpC} = \sqrt{\frac{jpL + R}{jpC}} = (a - jb)$$

Table I

f	a	b	a_1	b_1	$a+a_1$	$b+b_1$	$A^2=\frac{(a+a_1)^2}{10^4}$	$B^2=\frac{(b+b_1)^2}{10^4}$	A^2+B^2	$\frac{a_1 b}{10^4}$	$\frac{a b_1}{10^4}$	$\frac{a_1 b - a b_1}{10^4}$	$\frac{a^2}{10^4}$	$\frac{b^2}{10^4}$	$\frac{a^2+b^2}{10^4}$
10	248	210	400	264	648	474	41.99	22.47	64.46	8.40	6.55	1.85	6.150	4.41	10.560
20	186	150	338	159	524	309	27.58	9.55	37.13	5.07	2.96	2.11	3.460	2.25	5.710
30	158	123	316	116	474	239	22.47	5.71	28.18	3.89	1.83	2.06	2.496	1.51	4.006
40	139	106	304	84	443	190	19.62	3.61	23.23	3.22	1.17	2.05	1.932	1.12	3.052
50	126	95	300	73	426	168	18.15	2.82	20.97	2.85	0.92	1.93	1.588	0.90	2.488
60	118	86.4	298	65	416	151.4	17.30	2.29	19.59	2.58	0.77	1.81	1.392	0.746	2.139
70	113.0	79.0	294	54	407.0	133.0	16.56	1.77	18.33	2.32	0.610	1.71	1.277	0.624	1.901

Table II

f	$\frac{a_1^2}{10^4}$	$\frac{b_1^2}{10^4}$	$\frac{a_1^2+b_1^2}{10^4}$	$\frac{aa_1}{10^4}$	$\frac{bb_1}{10^4}$	$\frac{aa_1+bb_1}{10^4}$	λ	$2\alpha l$	$\sin 2\alpha l$	$\cos 2\alpha l$	$2\beta l$	$\cosh 2\beta l$	$N=\sinh 2\beta l$
10	16.00	6.97	22.97	9.92	5.54	15.46	1050	110°–0′	+0.94	−0.342	1.62	2.63	2.43
20	11.42	2.53	13.95	6.29	2.39	8.68	700	164°–8′	+0.26	−0.96	2.32	5.14	5.04
30	10.00	1.35	11.35	5.00	1.43	6.43	550	209°–24′	−0.494	−0.87	2.845	8.63	8.57
40	9.24	0.71	9.95	4.23	0.89	5.12	467	246°–30′	−0.92	+0.4	3.26	13.04	13.01
50	9.00	0.53	9.53	3.78	0.69	4.47	407	282°– 0′	−0.978	+0.21	3.71	20.44	20.41
60	8.88	0.42	9.30	3.52	0.56	4.08	368	313°– 0′	−0.743	+0.67	4.02	27.86	27.84
70	8.64	0.29	8.93	3.32	0.43	3.75	332	347°– 0′	−0.225	+0.97	4.27	35.77	35.75

Table III

f	$M=\cosh 2\beta l - \cos 2\alpha l$	$\frac{N}{M}$	u	n	u^2+n^2	$\pm 2u + (u^2+n^2)$	$\frac{N}{M}(A^2+B^2)$	$a_1^2+b_1^2 - (a^2+b^2)$	$(u^2+n^2)(aa_1+bb_1)$	$(u^2+n^2)(a^2+b^2)$	$u[a_1^2+b_1^2 - (a^2+b^2)$
10	2.97	0.818	−0.183	−0.316	0.1330	−0 233	52.7	12.41	2.06	1.41	+2.27
20	6.10	0.826	−0.175	−0.043	0.0324	−0.318	30.5	8.24	0.281	0.185	+1.44
30	9.50	0.902	−0.090	+0.052	0.0123	−0.173	25.2	7.35	0.0791	0.049	+0.72
40	13.44	0.968	−0.032	+0.0685	0.0058	−0.058	22.6	6.9	0.030	0.0177	+0.221
50	20.33	1.010	+0.01	+0.048	0.0027	+0.043	21.2	7.04	0.012	0.007	−0.0704
60	27.18	1.024	+0.025	+0.027	0.00135	+0.051	20.06	7.16	0.0055	0.003	−0.179
70	34.80	1.027	+0.027	+0.0065	0.00077	+0.055	18.77	7.03	0.0029	0.00146	−0.190

Table IV

f	$2n(a_1 b - a b_1)$	$(u^2+n^2 \pm 2u)(a_1 b - a b_1)$	$n[a_1^2+b_1^2 - (a^2+b^2)]$	K_1	K	K_2	$s_1=\frac{K_1}{K}$	$s_2=\frac{K_2}{K}$	$a'= s_1 a + s_2 b$	$b'= s_1 b - s_2 a$
10	−1.17	−0.431	−3.92	54.76	55.21	−4.35	0.992	−0.0786	229.51	227.81
20	−0.181	−0.671	−0.354	30.78	31.94	−1.025	0.963	−0.032	174.3	150.4
30	+0.214	−0.356	+0.382	25.28	26.2	+0.026	0.965	(Negligible 0.001)	152.6	118.6
40	+0.281	−0.119	+0.473	22.63	23.1	+0.354	0.980	0.0153	137.8	101.8
50	+0.185	+0.083	+0.338	21.21	21.32	+0.421	0.995	0.0197	127.2	92.0
60	+0.0977	+0.0923	+0.193	20.066	20.00	+0.286	1.003	0.0143	119.6	85.0
70	+0.0222	+0.094	+0.046	18.77	18.60	+0.140	1.009	0.00753	113.42	78.86

it follows that $A_1 = \dfrac{1}{\dfrac{jk}{jpC}\,\dfrac{\cos kl}{j \sin kl}} = \dfrac{1}{(a - jb)\dfrac{\cos kl}{j \sin kl}}$

$$\frac{\cos kl}{j \sin kl} = \frac{\cos \alpha l \cos j\beta l + \sin \alpha l \sin j\beta l}{\sin \alpha l \cos j\beta l - \cos \alpha l \sin j\beta l}$$

$$= \frac{-2j \sin 2\alpha l + e^{2\beta l} - e^{-2\beta l}}{e^{2\beta l} + e^{-2\beta l} - 2 \cos 2\alpha l} \quad (3a)$$

Put

$$\frac{\cos kl}{j \sin kl} = m + jn = k_1 \text{ where } n = \frac{-2\sin 2\alpha l}{e^{2\beta l} + e^{-2\beta l} - 2\cos 2\alpha l}$$

$$= -\frac{\sin 2\alpha l}{\cos h\, 2\beta l - \cos 2\alpha l}$$

$$m = \frac{e^{2\beta l} - e^{-2\beta l}}{e^{2\beta l} + e^{-2\beta l} - 2\cos 2\alpha l} = \frac{\sin h\, 2\beta l}{\cos h\, 2\beta l - \cos 2\alpha l} = 1 \pm u$$

then we can write

$$I_0 = \frac{\left[\dfrac{a_1 - jb_1}{k_1(a - jb_1)} + 1\right] V_0}{(a_1 - jb_1) + \dfrac{a - jb}{k_1}} = \frac{V_0}{\dfrac{(a - jb)[k_1(a_1 - jb_1) + (a - jb)]}{a_1 - jb_1 + k_1(a - jb)}}$$

$$k_1(a_1 - jb_1) + a - jb = m(a_1 - jb_1) + jn(a_1 - jb_1) + a - jb$$
$$= ma_1 + a + nb_1 - j(mb_1 + b - na_1) = P - jQ.$$
$$k_1(a - jb) + a_1 - jb_1 = ma + a_1 + nb - j(mb + b_1 - na)$$
$$= R - jS.$$

$$\therefore I_0 = \frac{V_0}{(a - jb)\dfrac{P - jQ}{R - jS}} = \frac{V_0}{(a - jb)\dfrac{PR + QS - j(RQ - PS)}{R^2 + S^2}} \quad (4)$$

Since $m = 1 \pm u$ it follows that

$$I_0 = \frac{V_0}{(a - jb)(s_1 + js_2)} \quad (5)$$

where

$$s_1 = \frac{(1 \pm u)[(a + a_1)^2 + (b + b_1)^2] + (n^2 + u^2)(aa_1 + bb_1)}{K} = \frac{K_1}{K}$$

$$s_2 = \frac{(n^2 + u^2 \pm 2u)(a_1 b - ab_1) + n[(a_1^2 + b_1^2) - (a^2 + b^2)]}{K} = \frac{K_2}{K}$$

$$K = (1 \pm u)[(a + a_1)^2 + (b + b_1)^2]$$
$$\mp u[(a_1^2 + b_1^2) - (a^2 + b^2)] + 2n(a_1 b - ab_1) + (n^2 + u^2)(a^2 + b^2)$$

If in eq 5 we put

$$\left.\begin{aligned} a' &= s_1 a + s_2 b \\ b' &= s_1 b - s_2 a \end{aligned}\right\} \quad (6)$$

Then a' and b' are the terminal resistance and reactance, respectively, of the composite cable, and eqs 6 are the equations of the terminal resistance and reactance curves. The question now is: Are these curves similar to the terminal resistance and reactance curves of the unloaded cable? In the following discussion this question is answered in the affirmative; it is shown that these curves can be employed in the design of a balancing network of the *composite* cable in a way similar to that employed in the design of the balancing network of a *uniform unloaded* cable.

The theory now will be applied to some specific case. For this purpose consider the cable discussed in an article by the author which was published in ELECTRICAL ENGINEERING for December 1931, p. 933–6. Suppose that this cable is uniformly loaded over a distance of 654.33 nautical miles of its middle part with an inductance of 30 mh per nautical mile, its terminal ends, each of length l = 160 nautical miles, being unloaded. Denote by a_1 and b_1 the terminal resistances and reactances of the loaded part at various frequencies, and by a and b the terminal resistances and reactances at the corresponding frequencies of the primary (unloaded) cable. In Tables I to IV a_1 and b_1 have been calculated by well-known formulas, and a and b have been taken from the previous article just referred to. The tables contain also all the quantities of eqs 6. The method employed in the calculation of the quantities recorded in these tables will be illustrated by calculating them for frequency 40.

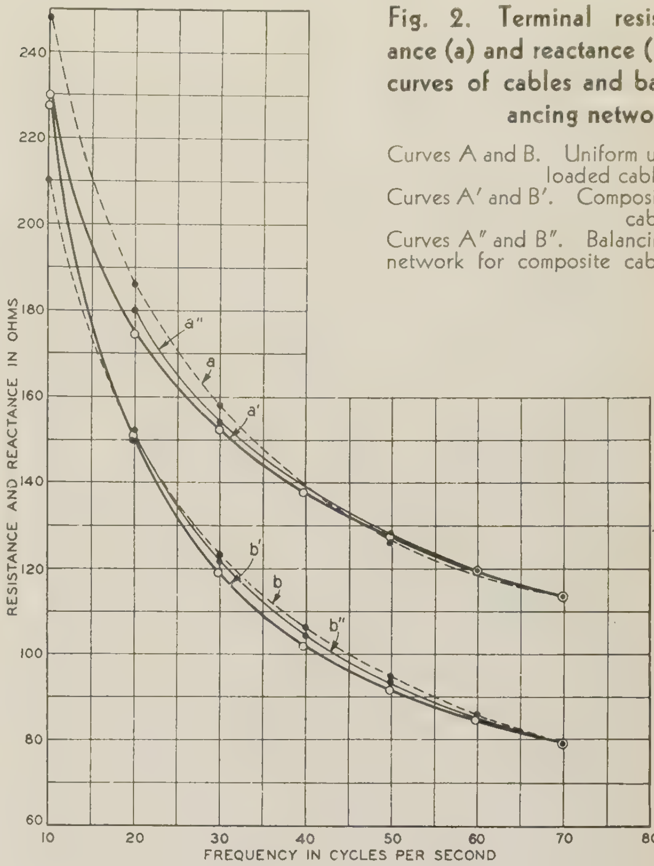

Fig. 2. Terminal resistance (a) and reactance (b) curves of cables and balancing network

Curves A and B. Uniform unloaded cable
Curves A′ and B′. Composite cable
Curves A″ and B″. Balancing network for composite cable

The wavelength λ at frequency 40 is given by the following equation:

$$\lambda = \frac{1}{fCa_{40}} = \frac{10^6}{40 \times 0.384 \times 139} = 467$$

Since $l = 160$ the angle $2\alpha l = 2\dfrac{2\pi}{\lambda}l = \pi\dfrac{4l}{\lambda} = \pi \times \dfrac{640}{467} = 246°\,30'$

Hence $\sin 2\alpha l = -\cos 23°\,30' = -0.92$
$\cos 2\alpha l = -\sin 23°\,30' = -0.3987$

$2\beta l = 2l \times 2\pi \times f \times C \times b_{40} = 320 \times 6.28 \times 40 \times 0.384 \times 10^{-6} \times 106 = 3.26$

$\cosh 3.26 = 13.04$
$\sinh 3.26 = 13.01 = N$
$\cosh 2\beta l - \cos 2\alpha l = 13.44 = M$

$$\frac{N}{M} = \frac{13.01}{13.44} = 0.968$$

$u = 1 - 0.968 = 0.032$
$2u = 0.064$

$$n = \frac{-\sin 2\alpha l}{M} = 0.0685$$

$n^2 + u^2 = 0.0058$

$$K_1 = \frac{N}{M}(A^2 + B^2) + (u^2 + n^2)(aa_1 + bb_1) = 22.63 = K' + K''$$

$$K = k' + u[a_1^2 + b_1^2 - (a^2 + b^2)] + 2n(a_1 b - ab_1) + (n^2 + u^2)(a^2 + b^2) = 23.1$$

$$K_2 = (-2u + n^2 + u^2)(a_1 b - ab_1) + n[a_1^2 + b_1^2 - (a^2 + b^2)] = -0.058 \times 2.05 + 0.0685 \times 6.9 = 0.353$$

$$s_1 = \frac{K_1}{K} = \frac{22.63}{23.1} = 0.979$$

$s_2 = \frac{K_2}{K} = \frac{0.353}{23.1} = 0.0153$

[illegible] $= 0.979 \times 139 + 0.0153 \times 106 = 137.7$
[illegible] $= 0.979 \times 106 - 0.0153 \times 139 = 101.7$

From the terminal resistance a' and reactance b', calculated in this manner, curves a' and b' of Fig. 2 were plotted. Curves a and b of the same figure represent the terminal resistances and reactances of the unloaded cable as determined by experiment, and described in the previous article referred to. A comparison of curves a' and b' with curves a and b suggests that down to frequency $f = 30$ the composite cable reacts at its terminals in a manner similar to the reaction of an unloaded cable, which I call its equivalent, and that, therefore, it can be balanced by the same method used in balancing unloaded cables. This method was explained in the article just referred to.

In order to apply this method to the composite cable it is necessary to calculate from its curves a' and b' (Fig. 2) the inductance curve L_1 and the resistance curve R_1 of Fig. 3. They are the curves of the effective inductances and resistances per 10 nautical miles of a uniform cable which is equivalent to the composite cable. The values of L_1 and R_1 were calculated by the formulas

$L_1 = (a'^2 - b'^2)10C; \quad R_1 = 2p \times 10Ca'b'.$

Following the method of balancing cables disclosed in the previous article, the network employed here

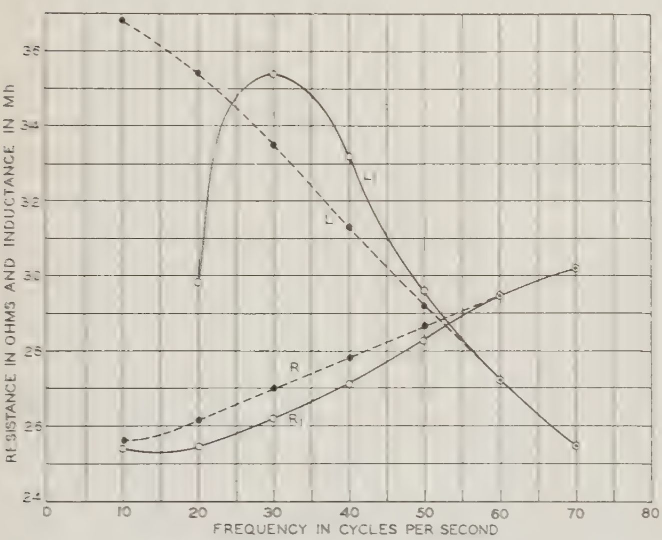

Fig. 3. Effective resistance and inductance per 10 nautical miles on the uniform unloaded cable "equivalent" to the composite cable (solid lines) and of each section of the balancing network (dashed lines)

consists of a sufficiently large number of equal sections, each section having 2 inductance coils connected in series. One of these coils has an inductance L and a resistance R and is shunted by a resistance R_1; the other has an inductance L_0 and a variable resistance R_0. The following formulas taken from the previous article give the effective inductance L_{10s} and the effective resistance R_{10s} of each section at frequency 10_s.

$$L_{10s} = \frac{L(1-a)^2}{1+s^2a_0^2} + L_0; \quad R_{10s} = R_0 + \frac{(a + s^2a_0^2)R_1}{1+s^2a_0^2}$$

$$a = \frac{R}{R+R_1}; \quad a_0 = \frac{2\pi 10L}{R+R_1}$$

The composite cable considered here can be operated at a speed of 1,500 letters per minute; hence the frequency interval between $f = 60$, and $f = 70$ will be taken as the fundamental frequency interval. From the resistance and reactance curves R_1 and L_1 of Fig. 3 we obtain: $R_{70} - R_{60} = 0.7$ and $L_{60} - L_{70} = 1.7 \times 10^{-3}$, hence

$$\frac{R_{70} - R_{60}}{L_{60} - L_{70}} = \frac{0.7 \times 10^3}{1.7} = 411.8 = q; \; a_0 = \frac{2\pi 10}{q} = 0.1525, a_0^2 = 0.0232$$

Applying these numerical relations in accordance with the method of the article referred to, the following result is obtained: $R_1 = 19.35$ ohms; $R_0 = 15.1$ ohms. Inductance L of the shunted coil is assumed to be equal to 0.1 h. The inductance of unshunted coil $L_0 = 15.15$ mh. Hence the effective inductance L_{10s} and resistance R_{10s} of each section of the inductive network are given by the formulas

$$L_{10s} = \frac{22.11}{1+s^2a_0^2} + 15.15; \quad R_{10s} = \left(\frac{0.443 + s^2a_0^2}{1+s^2a_0^2}\right)19.35 + 15.1$$

These formulas give: $L_{20} = 35.4$; $L_{30} = 33.5$; $L_{40} = 31.3$; $L_{50} = 29.2$; $L_{60} = 27.2$; $L_{70} = 25.5$ mh. $R_{20} = 26.2$; $R_{30} = 27.0$; $R_{40} = 27.8$; $R_{50} = 28.7$; $R_{60} = 29.5$; $R_{70} = 30.2$ ohms. Each section has a parallel capacity of 3.84 μf connecting the section to ground and represents 10 nautical miles of the equivalent cable. From these inductances and resistances the terminal resistances a_{10s} and reactances b_{10s} of the inductive balance have been calculated well known formulas on the assumption that the balance is sufficiently long. Thus: $a_{20} = 180.0$; $a_{30} = 153.8$; $a_{40} = 138.0$; $a_{50} = 127.7$; $a_{60} = 119.8$; $a_{70} = 113.6$; and $b_{20} = 151.7$; $b_{30} = 122.0$; $b_{40} = 104.4$; $b_{50} = 93.3$; $b_{60} = 85.2$; $b_{70} = 79.0$. These values were plotted as curves a'' and b'' of Fig. 2.

The terminal resistance and reactance curves of the inductive balance do not approach sufficiently closely to the terminal resistance and reactance curves of the equivalent cable at lower frequencies, and the balance here would be poor. In this respect also the composite cable resembles an unloaded cable, because the inductive balance just described cannot balance an unloaded cable at high speeds without a serious balancing defect at lower frequencies. Composite cables employ high speeds of transmission, hence they demand a balancing at higher frequencies; no balancing methods known today can give sufficiently satisfactory results when applied to such cables.

Employment of the mathematical theory developed here for the purpose of showing that a composite cable has an equivalent uniform cable and that, therefore, it can be balanced by an inductive balance just like any uniform cable is not the principal usefulness of this theory. Its greater value is in the aid which it affords to the design of a network which, connected in series with the inductive network just described, corrects its shortcomings in the operation of balancing at higher frequency intervals.

Mercury Rectifiers for 250-Volt Supply

The field of application of the multi-anode metal tank mercury cathode rectifier now available is outlined in this article with special attention to its adaptability to industrial load. Comparison of rectifiers with synchronous converters and motor generator sets is made, and loss and efficiency data are presented.

By
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ADVANCES which have been made in the quality and efficiency of mercury arc rectifiers in the past few years appear to make this type of conversion equipment at last suitable for use in at least a considerable part of the very large field of industrial applications requiring direct current at the nominal voltage of 250. The most important requirement, which is a sufficient degree of reliability for industrial service, is evidenced by installations with well over a year of practically uninterrupted service, over a wide range of load requirements.

The higher purchase price of power rectifiers has been an apparent rather than a real barrier to their use, since very often the lower installation cost and better all-day efficiency than for other types of conversion equipment, more than offset the price differential.

Rectifiers will not immediately supplant converters and motor generators for all or even a large part of industrial applications, but the present quality of the rectifier justifies an investigation in most cases for ratings of 50 kw and above, and for voltages of 250 and above. The promise of gains in efficiency and flexibility, and possibly in cost, for future designs gives present applications the further justification of providing the foundation for further progress.

The need for conversion equipment arises from the recognized superiority of the a-c system for generation and distribution, and from the necessity of providing for the large number of load requirements which today are met satisfactorily only by d-c motors. As the connecting link between a-c generation and distribution and d-c utilization, we first had the motor generator and later the more efficient synchronous converter. Thirty years ago the rectifying characteristic of mercury vapor in a vacuum was discovered. Since that time scientists and engineers have labored to produce practical mercury arc rectifiers. The first metal tank rectifier was built 24 years ago. In America, however, only within the past 5 years has there been any extensive use of metal tank mercury arc rectifiers in capacities of 500 kw and above, and with very few exceptions, the applications are limited to the higher voltages, 500 to 3,000 volts direct current, for electric railways.

The internal voltage or arc potential of a given mercury arc rectifier is nearly constant, increasing only slightly with load current; thus the efficiency of the rectifier is nearly constant. This internal voltage drop is also essentially independent of the terminal voltage, so the efficiency is approximately equal to the ratio of the output voltage to the output voltage plus the arc voltage. The internal loss determines the proportion of the rectifier design, and is proportional to the load current; therefore, the kilowatt rating is practically proportional to output voltage. Or roughly, a rectifier rated at 750 kw at 750 volts direct current, would be rated 250 kw at 250 volts direct current. On the other hand, a calculated weight of copper and iron will produce a generator of a given kilowatt capacity which, within certain limits, is independent of output voltage. So it is obvious that at the lower output voltages, the mercury arc rectifier is at a disadvantage from both the points of efficiency and cost.

The conventional type of rectifier becomes a competitor of the synchronous converter at approximately 500 volts, and has an increasing advantage in both efficiency and cost as the output voltage exceeds approximately 800 volts. The limits of the competitive range are altered somewhat with the larger single tank ratings, since in single tank rectifiers, limitations of design enforce an increase in arc potential, with a resultant decreasing of efficiency. The synchronous converter and the d-c generator, of course, do not have a similar limitation.

Recognition of the inherent advantages of higher efficiency coupled with adequate reliability and greater flexibility in both application and use for the smaller ratings, has lead to the development of the sectional type, in which large capacities are built up of smaller capacity sections capable of use either singly or in groups, as may be dictated by conditions of load, requirements of maintenance, etc. The concentration of development work on both the design and manufacture of a small number of designs has made possible the progress which now opens the way to the broad field of use for the 250-volt industrial applications.

D-C Frequently Required

Recognizing that direct current will always be necessary for certain industries, especially for electrolytic processes, consider specifically the field of the metropolitan system of d-c supply. The con-

Essentially full text of a paper based upon a talk presented before the power group of the Institute's New York, N. Y., Section, Nov. 29, 1932. *Not published in pamphlet form.*

version of alternating current to direct current in large centrally located substations, together with low voltage d-c distribution even in heavily concentrated load centers, has been recognized as costly and inefficient by comparison with a-c distribution. That this is recognized to be true even at the lower voltages is evidenced by the rapid growth of the low voltage a-c network system in many metropolitan areas. In a number of these, load is being transferred from the d-c to the a-c network, with the idea of ultimately eliminating the older d-c network. In nearly every case, new load is to be taken only on the a-c system.

Table I—Comparison of 300-Kw 250-Volt D-C Conversion Equipment, Based on Fig. 1

Avg % Load 8,600 Hours per Yr.	Saving in Losses —Kw	Annual Saving Kwhr	Annual Saving $ at 2c per Kwhr	Saving Capitalized at 15 %
Rectifier Equipment *vs.* Motor Generator				
12.5	17.8	153,000	$3,060	$21,000
25	17.0	146,000	2,920	19,500
50	15.6	134,000	2,680	17,900
75	13.3	114,000	2,280	15,200
100	10.4	89,500	1,790	11,900
Rectifier Equipment *vs.* Synchronous Converter Equipment				
12.5	6.7	57,600	$1,152	$7,680
25	5.2	44,700	894	5,950
50	2.2	18,900	378	2,520
75	−2.3	−19,800	−396	−2,640
100	−7.9	−68,000	−1,360	−9,060

Comparison of No-Load Losses

Motor generator	22.1 kw
Synchronous converter equipment	11.4 kw
Rectifier equipment	3.3 kw

Consumer investment in d-c utilization apparatus such as motors for elevators, pumps, blowers, and driving machinery is so great in many instances as to constitute a financial barrier to the execution of a program to change over completely to the a-c system within a short period of time. To provide for such d-c capacity as the consumer considers essential and to avoid excessive investment in a change over from one system to the other, and still take advantage of the higher efficiency of a-c generation and distribution, conversion apparatus of one type or another will be required. The type to be used should be selected on its merits, considering first cost (including installation), reliability, operating efficiency, operating cost, and maintenance.

Investment

Complete equipment for a small rectifier installation for 250-volt d-c supply will cost today probaby 50 per cent more than that for either a synchronous converter or a motor generator. But the increase in cost of the equipment may be largely offset by the lower cost of installation. There is usually a space on the consumer's premises that may be utilized for a small substation. This space very likely may be so located as to offer a serious problem in the matter of adequate ventilation for rotating apparatus. Also sound-proofing may be required to prevent complaints from noise-conscious tenants. Special foundations would of course be required. Since none of these is necessary for an installation of rectifiers, it is probable that the resultant lower cost of installation may in many instances more than offset the additional cost of the rectifier equipment.

Reliability

Studies indicate that mercury arc rectifiers, at least in capacities of 1,000 kw and less, at 600 volts, have on the whole records of service continuity at least equal to other types of conversion apparatus. Over the past year, a 3,000-kw 600-volt sectionalized type rectifier made up of 4 sections has established in heavy duty railway service a record of equal reliability. There is no reason to assume that in 250-volt service the reliability will be reduced.

Operating Efficiency

Through a comprehensive development program coupled with fundamental research and extensive laboratory and field testing, there has been produced a most reliable rectifier conversion equipment which based on a rating of 300 kw at 250 volts has an over-all operating efficiency including transformers and auxiliaries of slightly better than 90 per cent. In Fig. 1 and Table I data are given on such a rectifier compared with typical 60-cycle rotating machines. The relative over-all efficiencies include transformers for the converter and rectifier, but not for the motor generator. If the potential of the power supply is higher than 6,600 volts, transformers would be necessary also with the motor generator, with consequent reduction in over-all efficiency.

If the average load is less than 60 per cent of rated capacity, it will be noted that the rectifier is more efficient than the synchronous converter and that at $1/4$ load the rectifier has a favorable margin of approximately 5 per cent. Compared to the motor generator, the rectifier has a favorable margin of 3 per cent even at full load, while at 50 per cent load the rectifier is better by 7 per cent and at $1/4$ load by approximately 14 per cent. Idling losses of the rectifier are only approximately $1/7$ of such losses for the motor generator, and less than $1/3$ of those of the synchronous converter. Since the average load is often less than 50 per cent of machine rating, it is evident that the rectifier may be expected to have an operating efficiency perhaps as much as 10 per cent better than a motor generator and at least equal to that of a synchronous converter in the same service.

Operating Cost and Maintenance

Operating costs for completely automatic equipment would be approximately the same for all 3 types of conversion apparatus. The cost of maintenance should be but a small percentage of total annual charges. In general, high maintenance cost for rectifiers must result from trouble. There is nothing that wears out normally, as do the current

collecting parts of rotating machines, except for corrosion of the surfaces in contact with the cooling water. A reliable rectifier therefore should have less maintenance cost than a rotating machine. Even the corrosion of these surfaces is controllable.

Spare Capacity

Insurance to service continuity demands some measure of spare capacity. The usual requirements are that the maximum load shall be adequately served when the largest of a group of conversion units is out of service. Such insurance may be in the overload capacity of the serviceable units, in a complete spare unit, or a combination of the 2. Perhaps on the average the number of equipments installed will be 3, all of equal rating; this is logical for rotating machines, since with only one unit in operation during light load periods, or 2 units during maximum load, the units will be operating fairly efficiently. Considering the quite uniform efficiency of the rectifier, it is apparent that there is little further gain to be had in using a small unit at light load to improve conversion efficiency. Assuming a load to be supplied entirely from one automatically controlled rectifier, should an outage occur, the spare unit would be automatically put into operation with the lapse of only a few seconds. If even a momentary outage is a serious matter, both units might be operated continuously since even at fractional loads, the rectifier is relatively efficient. Considering then an installation of 2 rectifiers as against 3 motor generators or synchronous converters, the rectifier installation would have a total capacity $^1/_3$ greater than the 3-unit layout, but would still operate with higher overall efficiency than motor generators, but perhaps to no advantage over an installation of synchronous converters. The sectional arrangement of rectifiers applied in such a case makes for economy by providing readily for subdivision, reducing spare capacity requirements.

Neutral of 3-Wire System

The neutral of a 3-wire 125/250-volt system is ordinarily supplied either by a balance coil connected to the slip rings of a 3-wire d-c generator, or from the neutral of the transformers connected with a synchronous converter. The most efficient means of supplying the neutral to a 3-wire d-c service from a rectifier is to provide a 2-unit d-c a-c generator, the 2 units being connected in series across the terminals of the rectifier, with the neutral tap being made at the series connections. Since the load is ordinarily fairly well balanced, only a small capacity set would be required. But since the neutral is necessary only for lighting circuits and since conversion losses may be saved by connecting the lighting to the a-c system, a d-c neutral would not ordinarily be essential.

Regulation and Starting

Close voltage regulation is important only as a means of minimizing the flicker of lights and is not so important on power circuits. Therefore, voltage regulation such as of the order of 4 or 5 per cent which is inherent to a rectifier equipment should ordinarily be quite satisfactory. If, however, close voltage regulation is imperative it may be accomplished at some increase in cost in several different ways, but most probably by grid control.

Necessity for close voltage regulation of the a-c power supply may require that currents for starting large motors be limited to quite low increments. This results in an extension of starting time, and a material addition to the cost of control equipment.

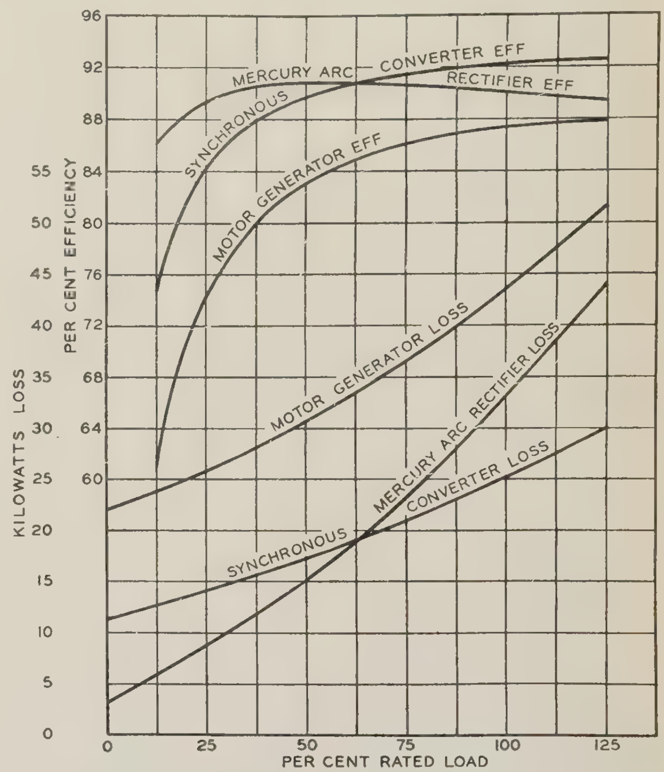

Fig. 1. Comparative curves of efficiency and losses for 300-kw 250-volt d-c conversion equipment with 440 to 6,600 volt 3-phase 60-cycle power supply

Efficiency and losses include auxiliaries and transformer for the rectifier, and transformer for the converter

Since there is no inertia to be overcome in starting a rectifier, it may be put into service by connecting directly to the power supply.

The study of specific examples will disclose many cases in which the rectifier is better suited to the requirements than any other type of converter. This gain in available conversion units will make it economically sound to proceed with some changeover projects which have not been justifiable previously.

As the developments in rectifiers progress at the present accelerated rate, further gains are to be expected in the matters of efficiency, size, cost, and controllability, and thus these gains will greatly enlarge the useful field of the mercury arc rectifier. The prospects seem most promising that the industry may soon begin to receive a return from the rectifier development commensurate with its very great cost.

Abstracts

Of Papers Presented at the Winter Convention—January 23–27

INTERPRETIVE abstracts of all papers presented at the technical sessions of the A.I.E.E. winter convention were published in the January 1933 issue of ELECTRICAL ENGINEERING, excepting only: (1) those papers upon which articles in that or preceding issues were based; and (2) those papers which at the time of going to press for that issue were not definitely scheduled for presentation. Abstracts of all remaining technical papers are presented herewith.

Members vitally interested and wishing to obtain a pamphlet copy of any paper available in that form may do so by writing to the A.I.E.E. order department, 33 West 39th Street, New York, N. Y., stating title, author, and publication number of each paper desired. In response to popular demand and within its space limitations ELECTRICAL ENGINEERING subsequently may publish certain of these papers, or technical articles based upon them.

Transients in Arc Welding Generators

By A. R. Miller[4]

THE TRANSIENT behavior of an arc welding generator, it is generally agreed, has considerable influence on the nature of the weld produced, both as to quality of weld and ease of manipulation. Several designs of generators have recently appeared which have been built to meet these requirements. This paper deals with the theory of armature and field current transients in such generators, giving the mathematical analysis and experimental results. From the tests were obtained oscillograms showing the effect of variation in the armature and field circuit inductance, and the mutual inductance between them.

It is the aim of the paper to show how these currents may be calculated by the simplest kind of processes, in complete generality and without the necessity of any approximations. The case of short circuit, or of change from one value of armature current to another, is analyzed, and the nature of the mathematical solutions is explained.

Either the field or armature circuit alone has only resistance and inductance, and consequently either when uninfluenced by the other would have as a transient, current of simple exponential form. It is shown that these currents take on this characteristic as the mutual inductance is reduced toward zero, the amplitude of the field current transient decreasing toward zero. When mutual inductance is present, there are reactions between the field and armature currents, and this effect is further modified by the armature rotational voltage as produced by the field current flux. Analysis shows that the overshooting of the armature transient current can be altered effectively by changing the field, armature, or mutual inductance between them, with somewhat different characteristics in each case.

That the short-circuit current shall not be excessive when the electrodes are brought together has been a rule with welding generators and this is determined by steady state conditions; it now appears that the transient current as well must be considered. This investigation has attempted to show how the machine constants may be used to determine the latter. **(A.I.E.E. paper No. 33-47)**

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Performance and Design of Electric Welders With Controlled Transients

By F. Creedy[4]

IN AN ATTEMPT to verify the theory previously given of electric welders with controlled transients, tests have been made on a neutralized welder and a standard type welder with and without a reactor transformer. Oscillograms show that while the standard machine has a large rise of current when short-circuited for 2 or 3 cycles of a 60 cycle wave, the machines with controlled transients have a very much reduced rise of current, and to this their improved performance partly is ascribed. A second important factor is the recovery of voltage after short circuit. It is shown that the function of the reactor transformer is to neutralize the mutual induction between the series and shunt fields of the welder, thereby rendering the field current more nearly independent of occurrences in the welding circuit.

At the moment of closing the circuit, 3 components of current exist. These are a steady state current, an armature transient, and a field transient. These components add up to zero. It is shown that to avoid overshooting on closing the circuit, the armature transient should be slow and the field transient small in magnitude and of rapid slope. The first condition may be met by large armature inductance and the second by low mutual inductance between field and armature circuit combined with a high time constant.

Oscillatory transients are considered in the paper, which it is stated make possible a clear physical explanation of the operation of the welder. Logarithmic transients also are considered and make possible a more complete understanding of welder design.

It is shown that there are 2 types of machines which control transients. The first relies on eliminating the mutual induction between field and armature circuits, and in the second all the inductive quantities are kept very low. With both machines, therefore, the rate of current changes is set by the external reactance, and the machine can follow all changes rapidly. **(A.I.E.E. paper No. 33-25)**

New Studies of the Arc Discharge

By J. L. Myer[22]

THE equation $V = A + B/I^n$ which represents correctly all normal arc characteristics is used as the starting point for a general discussion of arc phenomena and industrial applications. Tests of this equation are applied to iron arcs in various gas atmospheres to obtain a series of values for A and B making possible certain deductions about arc voltage variations and significance of the characteristics. In limiting the current exponent n, the anode temperature must exert considerable influence upon the discharge as a whole. Suggestions are given why this may be so. A value of n is predicted from the arc stream geometry, and is compared with actual values of n for various arcs.

19. Westinghouse Electric and Manufacturing Company, Sharon, Pa.
20. General Electric Company, Pittsfield, Mass.
21. General Electric Company, Schenectady, N. Y.
22. Engineering Foundation Research Fellow, at Lehigh University, Bethlehem, Pa.

The following concepts of the arc discharge phenomena are indicated from these new studies:

1. There is a "minimum energy" requirement of A watts per unit current in the arc conduction process, implying (a) a minimum of potential in drawing the charged particles into or out of the electrodes, and (b) the highest efficiency in conveying these charges through the arc stream. These conditions actually exist when the arc current approaches infinite values.

2. There is an "excess energy" requirement by virtue of the fact that the conduction efficiency decreases as the currents are farther removed from infinite values. Decreasing currents cause an increase in (a) the combined electrode falls, and (b) the surface losses per volume of the discharge column, which collectively represent the "excess energy" requirement of B/I^n watts per unit current.

3. These energy requirements per unit current combine to represent the voltampere characteristics. The functioning of the "excess energy" term B/I^n explains the falling slope of the characteristics, and the so-called "negative" resistance of the electric arc. In other words, the net efficiency of the arc increases with current.

4. The current exponent n indicates the rate at which the arcs approach "infinite current" conditions. As n is proportional to the anode temperature, this temperature appears to influence the ionization and absorption properties of the positive column, and therefore regulates the efficiency of these processes. On this basis, the high temperature arcs are the most efficient.

5. The largest portion of the "excess energy" losses probably result from heat and light radiation and ionic diffusion from the arc stream. There is evidence that this radiation and diffusion come from a cylindrical layer of the arc stream whose depth is inversely proportional to the gas temperature, so that in spite of the slightly increased surface of high temperature arcs their efficiency is still higher than for low temperature arcs.

6. In high current arcs there are considerable portions of the discharge which do not contribute to the surface losses. In falling through the electric field the ions in this non-radiating, high efficiency portion may acquire an extra energy over those near the surface. Under the effect of the directed field they would contribute this extra energy as heat to the electrodes. Energy equilibrium conditions at the welding arc cathode make such a suggestion plausible.

These studies tend to unify some general conclusions from seemingly unrelated experiments in giving a more complete physical picture of the arc discharge. Certain concepts should be useful in bringing theory and practice into better agreement, and enabling proper application of the arc in commercial problems. Above all, the need for correlated measurements on the arc discharge is emphasized. **(A.I.E.E. paper No. 33-41)**

Factors Influencing the Insulation Coordination of Transformers

By
F. J. Vogel[19]

IN THE early days of the electrical industry, surges were relatively mysterious as to their origin, magnitude, and behavior. The ordinary factory tests now required by the A.I.E.E. rules were the reflection of experience and judgment rather than the analysis which has been made possible in the last few years. From experience, it was found on the one hand that it was necessary to increase the insulation of some parts of the transformers far above the requirements of the A.I.E.E. rules (i. e., turn and coil insulation bushings) and, on the other hand, to limit the voltages transmitted to the transformer from the line, by the specification of line insulation and protective gaps. In the meanwhile, progress has been made in the laboratory study of the surge characteristics of the insulators, gaps, and insulation structures commonly used in transformers.

From the laboratory study it has been possible to determine the relationships existing between the present proposed coordination standards and the strength of the transformer insulation. The results of these tests show certain very interesting relationships among which are the effect of positive and negative waves, the impulse ratio of transformer major insulation, the fact that the present standard A.I.E.E. tests provide coordination with the proposed coordinating gaps for line voltages of 34,500 volts and above, and that the present A.I.E.E. tests are not adequate to provide coordination for voltage classes below 34,500 volts.

One of the most important facts developed is the small margin between the surge strength of transformer major insulation as determined by the standard A.I.E.E. tests and the proposed coordinating gaps at short time lags; this makes it desirable to maintain the level of surge voltage strength of the bushings to the lowest possible level which is suggested as 10 per cent above the proposed coordinating gaps. **(A.I.E.E. paper No. 33-38)**

The Measurement of High Surge Voltages

By
P. L. Bellaschi[19]

WITH the application of surge tests to high voltage electrical apparatus, the question of the measurement of high surge voltages has become a subject of prime importance. In Part I of this paper is shown the practical work done in a commercial laboratory to calibrate the measuring devices, and in Part II are studied the more interesting relationships that affect the operation and accuracy of these measuring devices.

The devices used for voltage measurement are the resistance potentiometer, capacity potentiometer, and sphere gap. The potentiometers serve as dividers of the high surge voltages for measurement at the cathode ray oscillograph. The cathode ray oscillograph is given an individual voltage calibration; it measures the stepped-down surge voltage across a component part of the voltage dividers. The resistance potentiometer is a fundamental standard but requires consideration of its limitations for very rapid surge phenomena. In cases where these can be compensated for or are negligible, the resistance potentiometer method is very desirable.

The resistance potentiometer has been used to calibrate a 200-cm sphere gap. The sphere gap is useful as a secondary standard for occasional check measurements, and it is of interest that formulas derived from smaller gaps still hold, as indicated by the check between the calculated curve for the 200-cm sphere gap and the calibration points with the resistance potentiometer.

The capacity potentiometer is a secondary standard which can be calibrated. If corona and oscillations can be eliminated, it is a very desirable method of measurement, inasmuch as it is less subject distorting the wave shape in the case of very rapid surge phenomena. Its other advantage is its freedom from damage due to transformer testing with dynamic power connected. **(A.I.E.E. paper No. 33-48)**

Impulse Voltage Testing

By
C. F. Harding[28]
C. S. Sprague[28]

EQUIPMENT and methods used for the surge testing of distribution transformers at the engineering experiment station at Purdue University are described in this paper. The surge generator of 1,000 kv maximum and the cathode ray oscillograph used in these tests are described. Curves are presented to show the desirability of ultra-violet illumination of the sphere gaps, especially for the smaller gaps and shorter spacings.

At the less steep wave fronts, calculated waves have checked fairly closely with the recorded waves, except on the rising front, where reflections across the discharge resistance are in evidence. The nature of these reflections and the manner in which they increase with increasing values of resistance are discussed in the paper.

Distribution transformers were tested with and without lightning arrester protection, in some cases up to the point of insulation failure.

Some of the more important conclusions resulting from these tests are:

1. With usual city conditions, consisting of a multiplicity of low resistance grounds on the secondary neutral, and the further possibility in some instances of a lightning arrester ground of high resistance, it has been demonstrated that the interconnection of the lightning arrester ground and secondary neutral definitely limits transformer stresses to values which should reduce lightning failures to a practically negligible quantity, even with the older non-surge-proof types of transformers.
2. Surge-proof transformers should have a reasonable factor of safety between insulation puncture strength and minimum bushing flashover values which should occur outside the tank, to assure, in case of failure of protective equipment, that the transformer insulation will not be damaged. This represents the more or less ideal case. However, if extensive use of the interconnection results in reducing flashovers and punctures to a negligible number with non-surge-proof transformers, the added cost of the surge-proof type may be warranted only for special installations.
3. The use of ultra-violet illumination of sphere gaps is conducive to greater accuracy and consistency of potential measurement, especially with potentials having steep wave fronts and with the use of smaller spheres and gap spacings. **(A.I.E.E. paper No. 33-51)**

28. Purdue University, Lafayette, Ind.

Coordination of Insulation

By
V. M. Montsinger[20]
W. L. Lloyd, Jr.[20]
J. E. Clem[21]

COORDINATION of system insulation is the selection of insulation in proportion to the anticipated overvoltages as limited by a coordination gap. A review of the development of coordination during the past few years is presented briefly in this paper, as a basis for discussing the means at present used for obtaining coordination of system insulation together with the advantages and disadvantages of various schemes. The 2 classes of overvoltage which may appear on a system, namely, switching surges and arcing ground voltages in the first class, and lightning voltages in the second class, are considered in respect to the selection of the coordination gap. It is pointed out that it is not logical to have steps or levels of insulation within a station, but that a uniform level of at least 10 per cent above the strength of the gap seems logical.

Location of the gap and the use of lightning arresters also are considered, and the necessity of further work for circuit voltages below 15 kv is pointed out.

Coordination of transformer insulation is considered in detail, attention also being directed to the coordination of potential and current transformer insulation, as well as transformer bushings. Advantages and disadvantages of the different types of coordination gaps are discussed, including the effect of humidity upon the lightning sparkover voltage. **(A.I.E.E. paper No. 33-39)**

Laboratory Measurement of Impulse Voltages

By
J. C. Dowell[20]
C. M. Foust[21]

IMPULSE testing of insulation and the precautions necessary to produce impulse voltages of the desired wave shape are treated in this paper. Such testing involves the construction of circuits of the proper electrical constants, the accurate measurement of these constants, the calculation of electrical variations in the circuit, and the checking of these calculations by indicating and recording instruments.

Recent experiences directed toward obtaining accurate results and a rigorous analysis of them may be summarized as follows:

1. Sparkover voltage differences with the $^1/_2$–5, 1–10, and $1^1/_2$–40 waves are believed to be more the result of differences in the wave length than in the wave front. By definition the waves differ by 8 to 1 in duration and only 3 to 1 in front. Moreover the waves do not rise uniformly to their crest values but rise rapidly at first and the large proportion of the total length of the front, particularly for the longer fronts, is consumed in approaching the crest. The difference in front is therefore even less than 3 to 1.
2. The resistance-capacitance and the resistance-cable voltage dividers are shown to be satisfactory when properly arranged. A carefully adjusted value of cable impedance is required for the resistance-cable divider. It is shown that on a fast or slow wave the calibration of the cathode ray oscillograph deflection in kilovolts per millimeter can be obtained and will check with either type of voltage divider.
3. The authors have recognized that an important cause of the disagreements between laboratories is the lack of uniformity and completeness in reporting results of impulse tests. A specimen table form which it is believed will at least suggest the lines along which reports should be made is presented. **(A.I.E.E. paper No. 33-49)**

Circuit Breaker Protection for Industrial Circuits

By
H. J. Lingal[2]
O. S. Jennings[29]

CONTINUITY of service, reduction in maintenance cost, and increase in safety to operators and property have made it necessary to improve the protective devices used in the distribution circuit. In the past, this protection has been provided by knife switches and fuses. The construction of circuit breakers occupying small space has recently been made possible through increase in design knowledge, and development of new materials, together with an increase in knowledge of arc phenomena and of arc interrupters.

The field of application of the new circuit breakers is stated to include switchboards, panel boards, load centers, meter entrance equipment, and enclosed switches. The principle of deionization is used in these circuit interrupters, the arc being broken into a number of short arcs and moved in an annular path until zero current is reached. Details of the construction and operation of these circuit breakers are described in this paper, and their advantages pointed out. The first circuit breaker is stated to have been built only in the 15-amp 125-volt size and had an interrupting rating of 5,000 amp; additional ratings since have been developed until now a line is available up to 600 volts and 600 amp. **(A.I.E.E. paper No. 33-50)**

29. Westinghouse Electric and Manufacturing Company, Mansfield, Ohio.

Recent Actions Taken by the Symbols, Units, and Nomenclature Committee

By
A. E. Kennelly[37]

IN REFERENCE to the cgs magnetic units, a brief historical outline is presented of the action taken by international electrical congresses from 1893 to 1904, and by international technical and scientific unions from 1904 to 1932. Emphasis is laid upon the results of the meeting of July 1932 of the symbols, units, and nomenclature committee of the International Union of Pure and Applied Physics, as the latest development.

The present status of international agreement on cgs magnetic units is unofficially presented, in the light of the historical background.

Turning to future possible developments, certain questions are pending for consideration, by either or both committees, in order to clear up any outstanding differences of international opinion over magnetic units in the classical cgs system.

In order to convert the existing series of practical electromagnetic units (ohm, volt, ampere, coulomb, farad, joule, watt, henry, and pramaxwell) into a complete system, international agreement must first be reached upon the 2 outstanding questions:

1. Subrationalizing ($4\pi NI$ or NI for mmf).
2. The unit of length to be adopted (meter or cm).

Suggestions are offered along both these lines. **(A.I.E.E. paper No. 33-52)**

New System of Recording Using Electronic Means

By
H. L. Bernarde[34]
L. J. Lunas[34]

AN ELECTRONIC recorder has been developed which will record d-c millivolts and microamperes at energy levels of 4 or 5 microwatts, and, with auxiliary equipment, will record feeble alternating currents and voltages. A pilot element attached to the measuring element of any usual type indicating instrument mechanism is connected in series with a second pilot element at the pen mechanism. A motor element for driving the recording element and carrying the second pilot element coil is driven by an amplifier which receives its indication from the difference in angular position of the 2 pilot elements. The stationary fields of both pilot elements are connected in parallel to the same a-c source.

As the torque on the pen motor is proportional to the difference in pilot coil position, a proportionate response action results, eliminating hunting. The equipment is free from errors resulting from changes in the characteristics of the vacuum tubes, changes in control voltage, frequency, or wave form, temperature changes, and stray fields. **(Paper for informal presentation only)**

34. Westinghouse Electric and Manufacturing Company, Newark, N. J.
37. Harvard University, Cambridge, Mass.

News
Of Institute and Related Activities

The Winter Convention in Review

CAREFUL planning on the part of the Institute's many committees was largely responsible for the success of the recent winter convention held in New York, N. Y., January 23–27, 1933. Through their efforts and cooperation, all events proceeded smoothly and enabled those in attendance to secure the maximum benefits from the technical sessions and inspection trips, and the greatest pleasure from the various entertainment features provided.

Alfred Noble Prize Presented at Opening Session

The convention was opened at 2 p.m. January 23 by H. P. Charlesworth, president of the Institute. After a brief tribute to H. H. Henline, now national secretary of the Institute, Mr. Charlesworth announced that the outstanding feature of this opening session was the presentation of the Alfred Noble prize to F. M. Starr (A'30), and placed the meeting in the hands of Arthur S. Tuttle, vice-president of the American Society of Civil Engineers.

This prize, as announced in Electrical Engineering for November 1932, p. 808–9, consists of an award of $500 from the income of a fund contributed by engineers and others in honor of Alfred Noble, past-president of the American Society of Civil Engineers and the Western Society of Engineers, for the purpose of perpetuating his many achievements. Mr. Tuttle stated that of all the members of the American Society of Civil Engineers, none had exceeded Alfred Noble in personal charm and in accomplishments. P. L. Alger then introduced Mr. Starr, outlining the events leading to the preparation of Mr. Starr's paper "Equivalent Circuits—I," upon which the award was based. Following Mr. Tuttle's formal presentation of the prize, Mr. Starr expressed his appreciation of this honor. President Charlesworth, after a few words of appreciation to E. B. Meyer, chairman of the general convention committee, turned the meeting over to W. H. Harrison, chairman of the technical program committee, who outlined the sessions and events to follow.

Technical Sessions

Activities at the 14 technical sessions are not included in this news report. Of the 58 papers presented, 15 already have been published in Electrical Engineering—one in the December issue, 8 in the January issue, 6 in this issue—and others are scheduled for subsequent issues. Of all papers not published in full or essentially full text, abstracts have been published, 38 in the January issue (all that were available at that time) and 11 in this issue. A résumé of the technical discussion is scheduled for the March issue.

Six Addresses Presented

In addition to the 58 technical papers, 6 addresses were included in the technical sessions. One of these, "Increasing Applications of Electricity to Chemical Processes," given by Dr. C. G. Fink, at the session on electrochemistry and electrometallurgy, is scheduled for presentation in full in a succeeding issue. On following pages of the present issue, abstracts are given of the following addresses: "The Professional Development of the Engineer," given by Gen. R. I. Rees, at the session on education; "Resistance of Storage Battery Separators and the Resistivity and Viscosity of Battery Electrolytes," given by Dr. G. W. Vinal; and "High-Conductivity Oxygen-Free Copper," prepared by P. H. Brace and Sydney Rolle, and read by J. V. Alfriend, Jr. These latter 2 addresses were given at the session on electrochemistry and electrometallurgy. An address on "Sound Measurement" by Harvey Fletcher was delivered principally to stimulate discussion at the meeting, and therefore is not included in these abstracts. Another address, "Some Phases of Present Day Economic Conditions of Particular Interest to Engineers," was delivered by Crosby Field at the session on industrial applications; publication of this address is contemplated for a future issue of Electrical Engineering.

Women's Entertainment

Entertainment for the women attending the Institute's winter convention included a luncheon and bridge at the Engineering Woman's Club on Tuesday, January 24. Independent theater parties and inspection trips of interest to women also were arranged. Mrs. E. B. Meyer was chairman of the women's committee, being assisted by Mrs. J. W. Barker, Mrs. T. F. Barton, Mrs. F. M. Farmer, Mrs. W. H. Harrison, Mrs. C. R. Jones, Mrs. G. L. Knight, Mrs. L. W. W. Morrow, Mrs. C. E. Stephens, and Mrs. H. R. Woodrow.

Buffet Dinner and Smoker

The annual smoker, held on Tuesday, proved to be one of the outstanding events, and was attended by about 650 persons. While the buffet supper was being served, moving pictures were being shown in the auditorium and continued until the specially arranged evening's entertainment began. This included a variety of features presided over by a most amusing master of ceremonies. R. A. McClenahen was chairman of the smoker committee which arranged this interesting event, assisted by E. S. Banghart, G. D. Edwards, W. H. Farlinger, J. E. Goodale, W. H. Harden.

Central News Photo

Frank M. Starr (right) shown receiving the Alfred Noble Prize for 1932 from Arthur S. Tuttle, vice-president of the American Society of Civil Engineers, with H. P. Charlesworth, A.I.E.E. president, as an interested observer. The presentation was made at the opening session of the winter convention

H. C. Schlaikjer, F. H. Stoppelman, E. F. Thrall, and H. G. Wood.

Annual Dinner Dance
Held at Hotel Roosevelt

Breaking away from the custom followed for the past few years of holding the Institute's annual dinner dance at the Hotel Astor, this event, always an outstanding one on the winter convention program, was held this year in the ballroom of the Hotel Roosevelt. The dinner dance, held on Thursday, January 26, 1933, was preceded by a reception in honor of President Charlesworth. About 350 persons were in attendance.

The dinner dance committee which arranged this attractive affair consisted of C. R. Beardsley, *chairman*, assisted by P. L. Alger, H. L. Huber, J. F. Kelly, R. F. Penman, C. S. Purnell, S. S. Reynolds, H. R. Searing, T. E. Shea, D. M. Simmons, George Sutherlund, and R. G. Warner.

Inspection Trips
Well Attended

Among the most popular of the inspection trips arranged this year were the trips to the Newark airport, busiest in the world, and the inspection of the new Radio City buildings, where unusual features in lighting and air conditioning could be observed. The registered attendance for the trip to the Newark airport was 151 persons, many of whom took advantage of the opportunity to fly over Newark Bay and lower New York, in the 12-passenger planes provided. The registered attendance for the 3 inspections of Radio City was 229, not including the many persons who visited the Music Hall and the theater for regular performances. The New York Museum of Science and Industry, and the scenic trip up the Hudson River, also proved attractive, and many members and guests visited the large number of industrial plants scheduled by the committee. A total of 720 persons registered for inspection trips.

Table I—Registration for 1933 Winter Convention

District	Registrants
New York City and Foreign (3)	791
North Eastern (1)	130
Middle Eastern (2)	132
Great Lakes (5)	23
Canada (10)	14
Southern (4)	4
South West (7)	2
North Central (6)	2
North Western (9)	1
Total	1,099

Table II—Registration at Recent Winter Conventions

1933	1,099
1932	1,429
1931	1,589
1930	1,607
1929	1,375
1928	1,475
1927	1,317
1926	1,423
1925	1,445
1924	1,738
1923	1,200

The inspection trips committee consisted of W. R. Smith, *chairman*, I. S. Coggeshall, G. F. Fowler, Henry Kurz, H. C. Otten, R. D. Parker, H. P. Sleeper, R. H. Twiss, and R. L. Webb.

Directors and
Committees Meet

In addition to a meeting of the Institute's board of directors, many meetings of committees were held. These were committees on standards, coordination of Institute activities, publication, finance, student branches, and technical program, as well as 11 technical committees and subcommittees. These were committees on automatic stations, electrical machinery, electric welding, transportation, electrochemistry and electrometallurgy, power generation, power transmission and distribution, education and sound; and subcommittees on distribution, and on transformers. The meeting of the board of directors is reported elsewhere in this issue. Since all the committee reports were not made available in time for this issue, they are scheduled for presentation as a group in a succeeding issue.

General and Executive Committees

The general convention committee and the convention executive committee are to be congratulated for their successful handling of the entire convention and the assisting of other committees in securing a smooth working organization. The general convention committee consisted of E. B. Meyer, *chairman*, J. W. Barker, T. F. Barton, F. M. Farmer, W. H. Harrison, C. R. Jones, L. W. W. Morrow, C. E. Stephens, and H. R. Woodrow. The convention executive committee consisted of C. R. Jones, *chairman*, C. R. Beardsley, R. A. McClenahen, Mrs. E. B. Meyer, and W. R. Smith.

The distribution of those officially registered for the 1933 winter convention is indicated in Table I, a total of 1,099 persons being officially registered. Registration of other recent winter conventions is indicated in Table II.

Edison Medal for 1932 Presented to Bancroft Gherardi

The highest award of the A.I.E.E., the Edison Medal, was presented for 1932 to Bancroft Gherardi (A'95, F'12, and past-president) "for his contributions to the art of telephone engineering and the development of electrical communication." A special session held on Wednesday evening, January 25, 1933, was the occasion for the actual presentation. Mr. Gherardi, vice-president and chief engineer of the American Telephone and Telegraph Company, New York, N. Y., has long been active in the Institute. (For a biographical sketch of Mr. Gherardi's accomplishments see Electrical Engineering for January 1933, p. 63.)

Following introductory remarks by the presiding officer, H. P. Charlesworth, the history of the Edison Medal was outlined by Dr. D. C. Jackson, past-president of the Institute and chairman of the Edison Medal committee. Doctor Jackson emphasized that the Edison Medal had proved to be a talisman of longevity, proving his point by citing the other Edison medalists. Doctor Jackson mentioned the world of regard and affection which was being bestowed upon Mr. Gherardi by his colleagues, who were not only handing him a golden disk of longevity, but were also expecting from him a long life of fertility and productivity.

President Charlesworth then introduced Gano Dunn, past-president of the Institute, who outlined Mr. Gherardi's career. Mr. Dunn's address follows:

Gano Dunn Delivers Address on Bancroft Gherardi

"If engineering is the art of the economic application of science to the purposes of man, then Bancroft Gherardi is an engineer par excellence. In the honorable roster of the aristocrats of electrical engineering held up for the world to see in the list of names on which the Edison Medal has been bestowed, there are forceful personalities whose careers lay emphasis now on one and now on another part of this definition without excluding the rest.

"In the careers of Thomson, Pupin, Millikan, Ryan, Jewett, science is strongly prominent. In the careers of Edison himself and of Stanley, Coolidge, Bell, Sprague, Brush, Carty, Lamme, Emmett, and Tesla, it is invention, along with certain other qualities, that stands out. In the careers of Westinghouse, Lieb, Rice, and Chesney we see the pioneer and industrial organizer.

"While each name in each of these groups and the names of others in the great list whom I have not mentioned represent all the elements of our definition, notwithstanding emphasis on different parts of it, Bancroft Gherardi probably represents a more even eminence in all the parts of it than any of the others.

"While his work is not salient in any one of the classifications, his effectiveness in all of them amounts to a sum so large as to bring about the distinction about to be conferred upon him tonight, which is a distinction that his professional peers see fit to confer only upon their outstanding men.

Genius of Judgment Shown

"Genius is often considered to lie only in invention and scientific intuition but there is a genius in judgment as well as in science and invention; and vision is but judgment projected into the future. There is also genius in a sense of proportion, balance, and the fitness of things that leads to eminence in organizations, even though the results of successful organization are

not capable of measurement so much by items as in the mass. The career of Bancroft Gherardi demonstrates, in addition to its other features, this genius of judgment and balance.

"If we agree that engineering is the art of the economic application of science to the purposes of man, the fiery crucible of the economic test is as essential to the rating of an engineer as is his constructive ability and his capacity for science. Gherardi has met this economic test, which involves knowledge of men and human relations, in a way that, alone, establishes his title to engineering distinction.

"The American Telephone and Telegraph Company and its subsidiaries through which Gherardi's work has been put to proof, is one of the greatest, if not the greatest, industrial organization of capital in the world, with telephone plant that has cost in the neighborhood of $4,000,000,000, representing expenditures in the engineers field that render the dollars successfully spent in accordance with Gherardi's recommendations probably greater in amount than the sums chargeable to the responsibility of any engineer in modern times. Of course all such responsibility is joint, but responsibility is a peculiar something that has a way of suddenly becoming particular when things go wrong.

"Gherardi's work has been built upon and assisted by that of his great master, a former Edison Medalist, the late John J. Carty; and coordinated with the work of particularly eminent associates notably Frank B. Jewett, another Edison Medalist, to all of whom he constantly acknowledges his indebtedness; but the commercial growth of the telephone industry since 1920 when Gherardi became vice-president and chief engineer of the American Telephone and Telegraph Company has assumed such huge proportions that the economic aspect of his engineering career cannot escape the emphasi that has here been given to it.

Early Career Outlined

"Equipped with a technical as well as a general training in the Brooklyn Polytechnic Institute and in Cornell University, from which he was graduated in 1894, Bancroft Gherardi is another vindication of John J. Carty's judgment of men. Starting in the New York Telephone Company under Carty's inspiration and education in 1894, Gherardi in 1900 was made chief engineer of the New York and New Jersey Telephone Company. In 1907 he was made engineer of plant of the American Telephone and Telegraph Company and in 1920 was promoted to be chief engineer and vice-president of that company, the great public service unit of the telephone art in the United States. These offices he discharges today with increasing distinction and prestige.

"A Fellow of the American Institute of Electrical Engineers, he was chosen to become our president in 1927. He has been president of the United Engineering Trustees and until recently was president of the American Standards Association. A member of the John Fritz Medal board of award, he had the honor of its chairmanship in 1930; and, in addition to memberships in technical societies and other honors, he is vice-president and director of the Planning Foundation of America and a trustee of Cornell University.

"The Emperor of Japan conferred upon him in 1923 the Fourth Order of the Rising Sun. In 1926 he took an important part in the negotiations that led up to the establishment of transatlantic telephone service with foreign countries and later was appointed the representative of the Bell System in charge of relations with the Comite Consultatif International which deals with international telephone affairs.

"Coming into the communication art when the telephone was young, involving only 300,000 stations in 1895, whereas it now involves 18,000,000 stations in the United States alone, he has played a most important part in the development and perfection of operating practices and in the development of methods, equipment, and apparatus which have brought telephone communication to the high state of perfection in which we find it today.

"He has directed the development and introduction of many new and improved arrangements now in use on a large scale, contributing greatly to the speed and accuracy of local and long distance telephone service. His broad vision as to the place occupied by communication in the affairs of the people of the United States and in world affairs and his initiative and skill in the development of engineering and operating organizations have contributed enormously to the growth and to the success of the art as it now is.

Technical Accomplishments Many

"His specific technical accomplishments are many but reference can be made to only a few. In 1895–97 he discovered a previously undiscoverable cause of corrosion in the lead sheaths of cables in cement lined iron pipe conduits. This corrosion previously assumed to be due to extraneous stray currents from the earth returns of electric street cars or other ground currents Gherardi showed was due to currents which the cable itself generated, acting as a battery of which the iron pipe was one plate, the lead sheath the other, and the moist cement between them, the electrolyte.

"He created a distinction, in telephone engineering design, between long toll line, and trunk, cables and short, subscriber cables, whereby the characteristics necessary for efficient transmission in long lines were preserved; but were sacrificed in the short lines which, on account of their lesser length, did not need them. As a result of this the duct capacity of subscriber cables at a time when duct capacity was at a great premium was immediately increased from 150 pairs to 200 pairs. This was the first step toward the 1,800 pair cables of today.

"By extensive experiment between 1897 and 1899, Gherardi established the fact that what is known as the *KR* law, a design formula used in predicting the characteristics of submarine cables, applied to all kinds of lead covered telephone cables.

Wide World Photo

Bancroft Gherardi receiving the Edison Medal for 1932 "for his contributions to the art of telephone engineering and the development of electrical communication." The ceremony took place during a special evening session of the winter convention. Left to right the A.I.E.E. leaders shown are National Secretary H. H. Henline, Past-President Gano Dunn, President H. P. Charlesworth, Past-President Gherardi, and Past-President Dugald C. Jackson, chairman of the Institute's Edison Medal committee

This enabled the talking characteristics of a cable to be determined before instead of after it was built.

Aerial Systems Redesigned

"When, about 1896, storm-proof aerial lead-covered cables were coming into use to supplant the vulnerable networks of aerial wires, Gherardi challenged the structural sufficiency of these new systems. He pointed out their weakness and caused them to be redesigned according to fundamental structural engineering principles so that they became in fact storm-proof.

"Standards of transmission were various in 1899 at which time Gherardi recognized the importance of definite norms to guide the designers of the rapidly growing art. He directed the experimental work and determined what the local and suburban standards should be.

"In 1900 he separated what are known in telephone practice as the "A" and "B" switchboards so that the ever increasing growth of the central offices could take place by extension, without the periodic upheavals and highly expensive reconstructions, which, growth beyond expected limits, from time to time, imposed upon the earlier type of boards, in which the "A" and "B" sections were combined.

"And similarly in 1900 while traffic engineer of the New York Telephone Company, he made the first general study of the proper method of handling toll calls in and about New York, that resulted in a new distribution between direct trunk and toll board traffic involving many economies and more prompt dispatch of business.

"In association with John J. Carty in 1902 Gherardi took part in the early tests and experiments of the New York Telephone Company at Columbia University, on Michael I. Pupin's invention for increasing the distance of telephone transmission through loading the lines with distributed inductance; and later he worked out the engineering problems in connection with the first Pupinized line between New York and Newark.

"Gherardi's influence on the adaptation of telephone buildings to their function has been great. Up to 1903 it had been the practice to locate the initial equipment of a central station in the back of the building and, as growth occurred, extend it toward the front beyond which growth could not take place on account of the limitations imposed by the street. Gherardi reversed this and made it standard practice to locate the initial equipment in the front, permitting building and other extensions in the rear as growth required in situations where the building did not cover the whole plot.

"Prior to 1916 automatic signaling over toll circuits required the use of a direct-current signal channel or its equivalent for each telephone circuit. Gherardi invented a system whereby a single direct current channel or other suitable telegraph channel could be used to provide signaling for a number of telephone circuits. His invention has been in operation ever since that time, notably between New York and Philadelphia, where it gives a capacity of signals for 240 telephone circuits over 8 telegraph channels.

"Perhaps one of the most responsible recommendations Gherardi ever made was for the adoption of the dial or machine switching system of switchboard connection gradually to replace the manual operation of local switchboards. In conjunction with K. W. Waterson then traffic engineer of the American Telephone and Telegraph Company, Gherardi directed the studies and reached the conclusion that this should be done. As chief engineer of his company he made a formal recommendation embodying his conviction and his recommendation for this epoch making change of practice was adopted by the officers of the Bell System and the great change is taking place.

"It is only occasionally that an engineer has to deal with the spectacular; but such was the solution of the problem of moving the central office in Indianapolis to a new location which Gherardi took the responsibility of approving. Instead of building a new building and then transferring the employees and equipment from one building to the other, the whole building, including employees equipment and all, was slowly moved to the new site without damage to the building or interruption to traffic; thereby saving the expense of a new building and the expensive taking down and reinstallation of the equipment to say nothing of saving the expense of provisions to maintain traffic during the operation.

A Philosopher As Well As An Engineer

"He could not have done what he has done as an engineer without being at the same time a good deal of a philosopher. With a mind and an intellectual curiosity broader than the demands of his immediate tasks, he has thought upon many subjects and published many papers, not only on scientific and economic topics in the telephone field but on such related subjects as the electrical discoveries of our great pioneer Joseph Henry in honor of whom the unit of inductance is named, and on the work of his predecessor, that dean of all telephone engineers, John J. Carty, on the occasion of Carty's receiving the John Fritz Medal a few years ago.

"He has also written the most complete and understanding presentation of the work of that remarkable scientist, pregnant inventor, and author of literature with a world appeal, Michael I. Pupin, and has done it in a way that reveals capacity for philosophic as well as technical treatment.

"Other publications of Bancroft Gherardi have reflected a universality of interest and capacity for observation and analysis which are undoubtedly at the bottom of the unusual judgment and vision by which his engineering work has been so distinctly characterized.

"In this brief estimate and perspective it is difficult to bring out more than the principal features of his career; and no reference has been made to personal qualities without which his leadership and success in organization would have been impossible.

"An honor from the outside can come from causes due to circumstance or to accident of position; but an honor from the inside like the Edison Medal which electrical engineers regard as their greatest honor, can come only from that broader knowledge of a man's quality and tested accomplishment that resides among his peers who know him best."

President Charlesworth Presents Medal to Gherardi

On behalf of the membership of the American Institute of Electrical Engineers, President Charlesworth then presented the Edison Medal to Mr. Gherardi, whose response follows.

"It is difficult for me to acknowledge this very great honor which my associates in the American Institute of Electrical Engineers have paid me in awarding me the Edison Medal and the honor which my friends and associates and other electrical engineers have done me this evening in giving me the reception which I have just received. I am deeply appreciative of it all and especially of the kind words of my good friend, Gano Dunn. He has, I think, seen my career through the rosy glasses of a friend, but there are times when one likes to have it done that way.

"I want to speak about one other group of people If this Edison Medal were to be cut up and to be distributed to all of those who are entitled to credit for the accomplishments for which I am being honored tonight, I am afraid that many of the pieces would require a microscope for their detection. There are so many to whom I owe obligations, not only of friendship but of support, cooperation, and assistance, and it is a great satisfaction to me to see many of them here in this audience this evening, and especially a satisfaction that in the chair as President of the Institute should be one who has been most closely associated with me for at least 20 years. If anything could add to the honor conferred upon me by my associates tonight, it would be the thought of the names and the achievements of the distinguished engineers who have received the Edison Medal in previous years. These men have represented many branches of electrical engineering and of science.

"Closely associated with communication, my own profession, are names from this roll of honor which you all know—Bell, Carty, Pupin, Jewett. One of these men, General Carty, who gave me my first job in the Bell System 38 years ago next month, was with us until the first of the year. Continuously for 35 years I worked in close association with him and a good part of the time reporting directly to him, and I cannot let this occasion pass without making acknowledgment of my deep obligation to him for the many things which I owe to this close association. At the moment, those of us who stood closest to him and have looked up to him are chiefly conscious of our loss, but as time goes on, although the sense of loss will not be diminished, we will see him in perspective and be able more and more to draw from his career and from his personality the inspiration which they offer.

"It is the custom for the recipient of the Edison Medal to offer to his associates and friends something from his experience. For many years, the position of the engineer in the social and economic structure has quite naturally been the subject of thought and discussion by engineers. Most engineering work has to do with things more directly than with people. The detailed execution of engineering work requires the understanding and use of a complicated technique which likewise has to do primarily with things. It is, therefore, inevitable that the engineer's training and experience,

especially in subordinate positions, tends to focus his thoughts upon things.

"Further, it seems to me likely that because of the nature of the technique and training, men whose primary interest is in things rather than in people adopt engineering as a profession. It is, however, not sufficient for engineering and more especially for those in the more responsible positions, to know only of things. Engineering is not done in a vacuum. Engineering is done in the world. Engineering is not done as an end in itself. Engineering is done that its products may be useful to mankind. The man who is in responsible charge of the engineering work of a large company, in order to fully understand its engineering problems, must understand the company's problems as a whole. He must understand the company, its functions, and its social and financial obligations. To do this, he must have some definite understanding of the public and of the society to whom the company is rendering service or furnishing goods. He is the connecting link between the engineering department, on the one hand, and the company and its customers on the other. To his department he must be able to interpret the company, its problems and its policies, to the end that these may be fully expressed in all of the engineering work done. To the company he must be able to interpret the possibilities and limitations of engineering as applied to its business, so that the company policies and objectives may be formulated and modified from time to time with due regard to the engineering factors which today form the basis for the operation of so many of our large undertakings.

"While the primary responsibility from this point of view rests upon the engineer in responsible charge, it is not only desirable, but it is quite possible for this idea to permeate the whole engineering personnel and be especially strong in all of the men holding key positions.

"While I have expressed my ideas of the relations of the engineer to his work and to society in terms of a company organization, it seems clear to me that it is equally true of any engineer in responsible charge of large undertakings, whether he is associated with a corporation, is the head of a consulting engineering organization or an engineer in charge of government or other engineering activities.

"To the extent that the engineer approaches his problems in this way, he will automatically become a part of the management of the undertaking with which he is associated. He will not just be working for it. To the extent that the engineer acquires this view of his profession and its relations to industry and to the world at large, I feel sure that he will have no cause to question his social and his economic status."

Lecture by Doctor Merriam

At the conclusion of the Edison Medal presentation, an address on "Evolution of Society As Influenced by the Engineer," was presented by Dr. J. C. Merriam, president of Carnegie Institution of Washington, D. C. In his address, Doctor Merriam eulogized the engineer for his development of facilities such as communication and transportation, which have tied the world together and made possible that close touch with affairs and personalities necessary to the success of democratic government. As of tremendous importance to the development of society, he also mentioned the increased leisure and time for thought which had been made possible by the development of machines.

In looking toward the future, Doctor Merriam suggested that the logic of science should be applied more energetically than in the past to the solving of sociological problems. The inevitable change in social conditions has brought a maze of problems, which could perhaps be solved by an application of the principle of "survival of the fittest," but which should be solved by an educated, clear minded, unselfish judgment.

The Professional Development of the Engineer

AT the session on education, held January 25, 1933, during the Institute's winter convention, New York, N. Y., an address entitled "The Professional Development of the Engineer" was delivered by Gen. R. I. Rees, vice-president of the American Telephone and Telegraph Company, New York. In his address, General Rees first discussed the education of the engineer up to the time of his graduation from college. Of the relative values of general and specialized education, he made among other remarks the following statements:

"Using the simple, but most difficult achievements (**Editor's note:** learning to walk and to talk) during our childhood simply as illustrations of distinct specializations in the learning process, do we not realize, as individuals, that our whole progress of development through life is made up of ascending series of specializations or foci of concentrations? At the period of life in which we find ourselves today, the major focus of our concentration is on our job, with minor concentrations demanded of us by our environment. But let us bear in mind that when our attention is given to any particular subject, we are at that moment specializing. So let us have done with specious argument concerning general and specialized education. Our professional development depends upon the wisdom with which we plan a sequence of concentrations on subjects and things to be done, which will promote the highest degree of progress toward the objectives of our careers."

Continuing with the subject of college education General Rees urged that a distinction not be made between cultural and technological education. He pointed out that all culture was divided into 3 parts, literary, scientific, and technical; and that Professor Whitehead of Harvard University states that no one of these cultures is complete in itself but must be strengthened by something from the other 2, and that when developed into a curriculum it becomes simply a question of emphasis.

General Rees next discussed post-college professional development, pointing out that while this development is a matter of individual responsibility, the engineering profession has come to realize that it can be of service to the young engineer in giving counsel and advice which will be helpful to him in his progress toward full professional recognition. As one means of accomplishing this service, General Rees mentioned the Engineers' Council for Professional Development. Outlining the history of the forming of this council, he mentioned 2 contributing factors, namely, the investigation of engineering education carried on by the Society for the Promotion of Engineering Education, and the investigation of the economic status of the engineer made by a committee of The American Society of Mechanical Engineers. As to the council itself, General Rees made the following statements:

"The first conference, having for its membership 3 delegates from each of these 5 societies (**Editor's note:** American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, and Society for the Promotion of Engineering Education) met in February 1932, approved the proposal for joint action in principle, and directed the chairman to appoint a planning committee and to invite representation to a subsequent conference of 2 other organizations, the American Institute of Chemical Engineers, and the National Council of State Boards of Engineering Examiners. The planning committee prepared a report which was submitted at a conference meeting held on April 14, 1932, and the plan submitted for the professional development of the engineer was given careful consideration, revised somewhat, and approved by the conference. The action taken at this conference was to submit the plan for adoption to the governing boards of the participating organizations. The plan was submitted to the societies at their spring and summer meetings, the final approval being recorded by the American Institute of Mining and Metallurgical Engineers on October 21, 1932, insuring participation of all 7 organizations. . . .

"The Engineers' Council for Professional Development is a conference of engineering bodies functioning to enhance the professional status of the engineer through the cooperative support of the national organizations directly representing the professional, technological, educational, and legislative phases of an engineer's life. To this end, it aims to coordinate and promote efforts and aspirations directed toward higher professional standards of education and practice, greater solidarity of the profession, and greater effectiveness in dealing with

technical, social, and economic problems. As constituted, the council has 3 delegates from each of the participating organizations.

"The immediate objective of the council is the development of a system whereby the progress of a young engineer toward professional standing can be recognized by the public, by the profession, and by the man himself, through the formulation of technical and other qualifications which will enable him to meet minimum professional standards.

"The council's program for professional development might be briefly described as follows:

"First, to develop further means for the educational and vocational orientation of young men with respect to the responsibilities and opportunities of engineers, in order that only those may seek entrance to the profession who have the high quality, aptitude, and capacity which are required of its members;

"Second, to formulate criteria for colleges of engineering which will insure to their graduates a sound educational background for practicing the engineering profession;

"Third, to develop a program for the further personal and professional development of young engineering graduates and a program for those without complete formal scholastic training;

"Fourth, to develop methods whereby those engineers who have met suitable standards may receive corresponding professional recognition.

"Concerning the method of operation, the Engineers' Council for Professional Development will, from time to time, recommend to governing boards of the participating bodies, procedures considered to be of value or significance in promoting the general objective and will administer such procedures as have been approved by those boards.

"Considerable progress has been made in the organization of the council. An executive committee has been appointed from the membership, composed of one member from each of the participating organizations. The organization of other committees is now in progress. Their duties are considered to lie in certain distinct fields, arranged in a time sequence contributing to the full development of the young engineer.

"The committee on student selection and guidance, as its name implies, will be responsible for developing ways and means to carry out the first element in the program. One significant contribution to the work of this committee already has been made through the publication by the Engineering Foundation of the booklet entitled, 'Engineering—A Career, A Culture.'

"The committee on engineering schools will devote its efforts to bringing about a high degree of cooperation between the engineering profession and the engineering schools. This cooperation will be tendered by the profession in a spirit of helpfulness, with a full realization that the responsibility for the development of engineering education lies with the engineering schools. One undertaking which seems to require immediate attention is that set forth in the second item in the program—the development of criteria for colleges of engineering which will insure to their graduates a sound educational background for practicing the engineering profession.

"The committee on professional training will function on the third item of the program. It will endeavor to be helpful to the young engineer in arranging a program of personal development which will bridge the gap between graduation and full professional recognition. The major part of this program, of course, will be experience, gained in the practice of the profession. This committee can be of most service in suggesting subjects for study which will contribute most to intellectual development and which will prepare the young engineer to meet the requirements set forth by the committee on professional recognition.

"Much study must be devoted to determining the average length of time which the graduate must spend in preparing himself for full professional status. It will depend largely on the qualifications decided upon. Tentative discussion within the Council would seem to indicate that this period might cover 5 years after graduation, or a longer period for those men who have not had complete formal engineering training.

"The committee on professional recognition covering the fourth element in the program will set the goal for full professional status. Again much study must be devoted to the determination of objectives and a definition of the criteria which must be met. The nature of the award which will give evidence of full professional recognition must also be determined. Members of the Council, in preliminary discussion, suggested a number of awards, such as full membership in the professional societies, the granting of the professional degree by the engineering colleges, and licensure in those states requiring registration and license of engineers. In fact, professional recognition might include all 3 of these awards. Surely they are goals worth striving for, and will add much to the engineer's prestige.

"Contemplating the program as a whole, it becomes evident that the council is responsible for maintaining contact with the young man from the time he begins to think about his life's career, as an applicant at the gates of his chosen engineering college, as a student and graduate, through his novitiate of practical experience, and further intellectual development, until that time comes when he stands beside his fellows, recognized as a professional engineer. It covers a spread of fully 10 of the most vital years of a man s life. Here is a cause worthy of the devoted service of every member of the great national engineering organizations. When the program begins to function it will require the active participation of divisions, local sections and chapters, and student sections, as well as all engineering schools. Success demands the united wisdom of the whole profession."

Storage Battery Separators and Battery Electrolytes

An address on "Resistance of Storage Battery Separators and the Resistivity and Viscosity of Battery Electrolytes" was delivered by Dr. G. W. Vinal of the U.S. Bureau of Standards, Washington, D. C., during the session on electrochemistry and electrometallurgy held on January 26, 1933, as part of the Institute's recent winter convention in New York, N. Y. An abstract prepared by Doctor Vinal summarizing his address is as follows:

"A method for measuring the resistance of storage battery separators was described by Snyder in Bureau of Standards Technologic Paper No. 271, in 1925, and has since found use in the industry. More recently an improved method has been developed by which the accuracy of measurement has been greatly increased and measurements may now be made at extreme low temperatures with little more difficulty than at ordinary temperatures. In the course of the recent experiments the need for determining the resistivity of sulphuric acid solutions at low temperatures became evident, since the resistance of wood separators increases more rapidly as the temperature is lowered than the resistivity of the solution for a corresponding change. Closely allied with this problem, the viscosity of sulphuric acid solutions at low temperatures is an important factor affecting the diffusion of electrolyte throughout the cell. Basic data, not previously available, covering both resistivity and viscosity of sulphuric acid over a wide range of temperatures have now been obtained.

"The new method for measuring the resistance of separators consists in cutting disks about 3.5-cm diam from a considerable number of samples and measuring the change in resistance of a small electrolytic cell when the disks are placed between the electrodes. The disks are cut with a steel die of such size that they fit accurately in the glass tube of the cell. The electrodes are lead, covered with lead peroxide. The upper electrode may be removed to permit the disks to be inserted, but its position with respect to the lower electrode is fixed by ground glass surfaces at the top and bottom of the tube. The cell is small and is placed in an outer vessel containing electrolyte of the required concentration. This in turn may be placed in a temperature-controlled bath.

"Measurements are made on a wheatstone bridge having 2 fixed ratio arms of 10 ohms each and a slide wire between the remaining arms for fine adjustment. The bridge is supplied with current from a 1,000-cycle oscillator. Earphones connected through a 2-stage amplifier are used in the detector circuit in balancing the bridge.

"A variety of samples including Port Orford cedar, cypress, Spanish cedar, and 3 kinds of porous rubber have been tested. Progressive changes in the resistance, particularly of wood specimens, have been noted, depending upon the time of immersion. These changes give some indication of the effectiveness of the treatment to which the samples were previously subjected. After several weeks' immersion in the acid, the resistance becomes relatively constant. The percentage increase in resistance of porous rubber samples is practically the same as the percentage increase in resistivity of sulphuric acid solutions when the temperature is lowered to −15 deg C, but the percentage increase in resistance of wood specimens is about 50 per cent greater.

"Resistivity of sulphuric acid within the range of concentrations used for batteries has been measured from +30 deg C to −40 deg C. Conductivity cells of the

usual form were used with the same bridge as for the separator measurements. The resistivity of the solutions at -40 deg C is about 9 times that at $+30$ deg C. Below 0 deg C the increase in resistivity is very rapid.

"Viscosity of sulphuric acid solutions within the range $+30$ deg to -50 deg C has been determined by the flow of the solutions through a capillary tube which was calibrated by liquids of known viscosity, including water, sugar solutions, alcohol, and oils. Below 0 deg C the viscosity was found to increase very rapidly as the temperature was lowered. Data in this range have not previously been available."

High-Conductivity Oxygen-Free Copper

An address, "High-Conductivity Oxygen-Free Copper," by P. H. Brace, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., and Sydney Rolle, U.S. Metals Refining Company, was scheduled for presentation at the session on electrochemistry and electrometallurgy, January 26, 1933, during the Institute's recent winter convention. In the absence of Mr. Brace, the previously prepared address was read by J. V. Alfriend, Jr.

In this address, the different methods of refining copper were first mentioned, together with the percentages of impurities resulting. Previous methods of refining "blister" copper involved the use of fuels which introduced impurities into the copper. In order to reduce these impurities air is blown through the molten copper and the resulting oxides must be removed as far as possible by the chemical action involved in "poling"; this consists of introducing wood poles into the bath. The copper then can be cast.

Electrolytic refining is an improvement on this method, but results in a copper having physical characteristics that are undesirable for wires and similar objects. Before being used, the copper must be remelted and the impurities introduced must again be taken out as far as possible, before the metal is cast. During casting the exposed surface absorbs more oxygen, efforts to reduce which have included the use of deoxidizers as well as casting the metal vertically to reduce the exposed surface.

Difficulties resulting from these methods brought about an effort to melt the pure cathode copper in an electric furnace having accurate temperature control, thus eliminating impurities from furnace fuel. It was stated that several years of experiments enabled vertical casting to be produced of uniform quality and free from both oxygen and residual deoxidant. Engineering information regarding details of this method were not given in the address, but slides were shown which indicated the advantages of high-conductivity oxygen-free copper. It was stated that further work is being done on this method. Fatigue information and conclusions are still in a formative state. Oxygen-free copper appears to be of definite interest as an engineering material when fabrication or service conditions are important.

In Memoriam

JOHN J. CARTY

WHEREAS, the death on December 27, 1932, of General John J. Carty, a member of the Institute for more than forty years and an Honorary Member since 1928, removed an outstanding leader in science and its applications;

WHEREAS, through his many personal creations of important devices and methods and his extraordinary ability to analyze a problem in all its details, and to coordinate and direct the efforts of others, his achievements in the development of modern telephony, both wire and radio, became recognized throughout the world;

WHEREAS, he received high recognition for his activities in the Signal Corps of the United States Army and made other important contributions to the public service;

WHEREAS, as a member of important Institute committees, as vice-president, as a director, and as president (1915–16), he made many contributions to the development of the Institute according to the highest ideals, be it therefore

RESOLVED: That, on behalf of the membership, the board of directors of the American Institute of Electrical Engineers hereby expresses its profound sorrow at the death of General Carty, and extends its sympathy to the members of his family; be it further

RESOLVED: That these resolutions be entered in the minutes and copies be transmitted to members of his family.

Directors Meet During Winter Convention

The regular meeting of the board of directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Wednesday, January 25, 1933, during the annual winter convention of the Institute.

There were present: *President*—H. P. Charlesworth, New York, N. Y. *Past-presidents*—W. S. Lee, Charlotte, N. C., and C. E. Skinner, East Pittsburgh, Pa. *Vice-presidents*—L. B. Chubbuck, Hamilton, Ont.; W. E. Freeman, Lexington, Ky.; J. Allen Johnson, Buffalo, N. Y.; W. B. Kouwenhoven, Baltimore, Md.; E. B. Meyer, Newark, N. J. *Directors*—L. W. Chubb, East Pittsburgh, Pa.; A. B. Cooper, Toronto, Ont.; B. D. Hull, Dallas, Tex.; A. E. Knowlton, New York, N. Y.; G. A. Kositzky, Cleveland, Ohio; A. H. Lovell, Ann Arbor, Mich.; F. W. Peek, Jr., Pittsfield, Mass.; C. E. Stephens, New York, N. Y.; A. C. Stevens, Schenectady, N. Y.; H. R. Woodrow, Brooklyn, N. Y. *National Treasurer*—W. I. Slichter, New York, N. Y. *National Secretary*—H. H. Henline, New York, N. Y.

Minutes were approved of a meeting of the board of directors held October 12, 1932, and of a meeting of the executive committee held December 6, 1932.

A resolution was adopted in memory of John J. Carty, a past-president and an Honorary Member of the Institute, who died on December 27, 1932. This resolution is published elsewhere in this issue.

Reports of meetings of the board of examiners held December 8, 1932, and January 18, 1933, were presented and approved. Upon the recommendation of the board of examiners the following actions were taken upon pending applications: 1 applicant was elected and 9 applicants were transferred to the grade of Fellow; 9 applicants were elected and 20 were transferred to the grade of Member; 276 applicants were elected to the grade of Associate; 508 Students were enrolled.

The finance committee reported approval, for payment, of monthly bills amounting to $16,980.06 in December and $19,173.77 in January.

A resolution was adopted to the effect that the 1933 Annual Meeting of the Institute will be held in Chicago, on Monday, June 26.

Upon the recommendation of the committee on coordination of Institute activities decision regarding a schedule of meetings for the calendar year 1934 was postponed to the next meeting of the board of directors.

Upon request of the Sections concerned, and with the approval of the Sections and finance committees, authorization was given for the transfer of the members residing in Vigo and Clay Counties, Indiana, from the Urbana Section to the Indianapolis-Lafayette Section.

Upon recommendation of the standards committee, the board of directors approved, for submission to the American Standards Association, a revision of A.I.E.E. Standard No. 38, "Electric Arc Welding Apparatus," and A.I.E.E. Standard No. 39, "Resistance Welding Apparatus," developed by the sectional committee on electric welding apparatus. Also, the board approved for

adoption as American Standard, the inch-millimeter conversion factor 25.4 for general industrial use instead of the present factor of 25.40005.

Representatives were appointed as follows: Dr. Charles F. Scott to serve on the Assembly of American Engineering Council, to succeed Mr. H. A. Kidder, resigned; Dr. Charles F. Scott to serve on the U.S. National Committee of the International Commission on Illumination, to succeed Dr. C. O. Mailloux, deceased; Messrs. F. W. Peek, Jr., and C. E. Skinner to serve on the council of the American Association for the Advancement of Science, for the year 1933.

Other matters were discussed, reference to which may be found in this and future issues of ELECTRICAL ENGINEERING.

A Safety Problem Worthy of Attention

Here is a brief outline of 2 different accidents as reported to the National Safety Council, Chicago:

"*First:* The control cords of an electric crane in a large shop were out of position on the sheave. A shop man preparing to make the needed adjustment, placed a ladder with top end resting against crane rail. After opening the switch deenergizing the crane he requested another employe to hold the bottom of the ladder. He then climbed the ladder adjusted the control cords, came down, closed the switch and tested the cords which were found to still be out of adjustment. Without again opening the control switch he hurriedly climbed the ladder, apparently forgetting the equipment was energized, and pulled one of the control cords. With the pulling of the cord the crane was set in motion, knocking the ladder from under him. To save himself from falling he grasped the crane rail with both hands directly ahead of the traveling crane which passed over both his hands before the man holding the ladder could stop the crane. The injured employe then fell to the floor with all fingers badly broken and crushed.

"*Second:* A substation operator, with nine years electric utility experience, who had been carefully trained in all phases of operating the particular substation involved went into the substation to replace a fuse which had blown. His first move was to correctly deenergize and ground the equipment involved. The blown fuse was then replaced and the equipment energized in the proper manner. The new fuse immediately blew out, the operator apparently became puzzled for an explanation of the trouble, secured a new fuse and without again deenergizing the equipment, which he knew was necessary as evidenced by the fact he had done so in the first instance, took his position to replace the blown fuse and received an electrical shock which rendered him unconscious.

"In both cases mentioned, as in other similar accidents, the men involved knew the dangers present and understood clearly the safe methods of procedure. Yet both were victims of their own thoughtlessness."

These instances, quoted from the Council's November 1932 *News Letter*, serve well to emphasize the important fact that safety devices and safety rules must be supplemented by unrelenting safety education if accidents are to be prevented. "Accidents do not happen—they are caused."

Engineers Cooperating for "A Century of Progress"

Engineers' Day at the Century of Progress Exposition, Chicago, Ill., is to be held on Wednesday, June 28, 1933, as an outstanding feature of "Engineering Week." The principal engineering societies and the American Association for the Advancement of Science are cooperating to assure the success of "Engineering Week," which extends from June 25 to 30. Among the conventions which will be held at this time is the Institute's annual summer convention scheduled for June 26–30, with headquarters at the Edgewater Beach Hotel, Chicago. None of the engineering societies is planning any individual activities for Engineers' Day, on which all engineers will assemble for special ceremonies. Arrangements are progressing to make this an occasion of international importance, as many engineers and scientists known throughout the world will be in Chicago at that time. Details of these events will be announced in future issues of ELECTRICAL ENGINEERING.

An engineering societies committee on the Century of Progress Exposition has been appointed to make arrangements for "Engineering Week," with representatives from the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the Western Society of Engineers. The Institute's representatives on this committee are T. G. LeClair (A'24, M'29), J. G. Wray (A'99, M'11, F'13), and W. M. Vandersluis (A'19, M'28, F'29).

Past-President C. E. Skinner Retires

After having served the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., since August 16, 1890, Dr. C. E. Skinner, assistant director of engineering for that company, retired January 1, 1933.

In Institute affairs Doctor Skinner has been an active leader for more than 20 years. He became an Associate in 1899, was transferred to full membership in 1903, and became a Fellow of the Institute in 1912. In addition to his executive service to the Institute as a manager (1915–19), as vice-president (1919–20), and as president (1931–32), he has been an active member of 14 of the Institute's more important technical and executive committees, and has served as the Institute's active representative on 11 inter-society or international bodies. He has served continuously since 1914 on the Institute's standards committee; for the same period of time he has been the Institute's representative on the U.S. national committee of the International Electrotechnical Commission, and has been abroad several times as an active participant in the commission's undertakings.

In the service of the Westinghouse company, Doctor Skinner has pioneered many developments of importance to his company and to the electrical industry at large. He was a pioneer in the organization of an orderly program in the field of electrical insulation research and development; organized an orderly program in process engineering and in the arrangement of materials specifications. Doctor Skinner was a consistent leader in Westinghouse research efforts, and is credited with the organization of various laboratories, culminating in the organization of the coordinated Westinghouse research laboratory and the erection in East Pittsburgh of a special building to house its many departments.

Although technically retired to private life, Doctor Skinner undoubtedly will pursue his several personal interests, and continue professionally active.

Highest Crossing in the World

The erection of 2 towers for conveying 2 3-wire 132,000-volt circuits across the Thames River below London, England, has been finished for the Central Electricity Board. The completed crossing is stated to be the highest in the world. The towers themselves form part of an overhead line from Barking power station to the Northfleet substation of the Central Electrical Board, and are erected on the north side at Dagenham, close to the new Ford Works, and on the south in the grounds of the Woolwich Arsenal, the great British depot for war material on the southern bank of the Thames below London. The crossing itself comprises 2 main suspension towers, each 487 ft high with an anchor tower at each end 105 ft high. The respective spans are 1,500 ft, 3,060 ft, and 1,500 ft and a minimum clearance at high water of 250 ft is provided, which would allow the "Majestic" to pass under with 30 ft to spare.

The design of the crossing as a whole hinges very largely upon the material used for the conductors, economy in capital cost of the towers tending in the direction of using conductors of high tensile strength, thus reducing the height of the towers.

It is very necessary to consider also the durability of the conductors in the atmospheric conditions to which they are exposed, and the choice ultimately fell on a composite conductor having a 90-wire strand, the diameter of each wire being 0.0856 in. The 7 center wires are of cadmium copper and are surrounded by 84 wires of phosphor bronze. The overall diameter of the strand is therefore 0.942 in.

It was necessary to pile the foundations for all towers and in the case of the suspension towers from 12 to 14 reinforced concrete piles 60 ft long were required for each leg. The base of these towers at ground level is 120 ft square.

A stairway provided with hand-rails enables an easy ascent to be made for 387 ft, the remaining distance having to be negotiated by means of a combination of stairways and ladders. The design of the structures is such that if necessary at some future date an elevator can be incorporated. There is over 300 tons of steelwork in each of the suspension towers.

Perkin Medal Presented.—The Perkin Medal of the Society of Chemical Industry was presented to George Oenslager of the B. F. Goodrich Company, Akron, Ohio, at a meeting held January 6, 1933, in New York, N. Y. This award is made by a joint committee of members of the Society of Chemical Industry, the American Chemical Society, the American Institute of Chemical Engineers, the Electrochemical Society, and the Societe de Chimie Industrielle. The medal was presented this year to Mr. Oenslager for his contribution to the rubber industry.

Edwin Gruhl, Utility Executive, Dies

Edwin F. Gruhl, president of the North American Company, died unexpectedly January 22, 1933, at his home in New York, N. Y. He was 46 years old. A native of Milwaukee, he graduated from the University of Wisconsin in 1908, and was then in charge of the statistical and research departments of the state railroad commission until 1911 when he joined the faculty of the University of Wisconsin. After one year in this position he left to become assistant to the vice-president of the North American Company, remaining with this organization the rest of his life. He was successively promoted to the positions of assistant to the president, vice-president, general manager and a member of the board of directors, and, on April 25, 1932, president.

Mr. Gruhl was president of the Association of Edison Illuminating Companies, and was active in the recently created Edison Electric Institute. He was vice-president and director of Associated Music Publishers, Inc., and was a member of many clubs in New York, Chicago, Milwaukee, and Madison, Wis.

Funds Available for Relief of Engineers

The engineers' national relief fund, a joint activity of the national societies of civil, mining and metallurgical, mechanical, and electrical engineers, has continued to aid members of the societies during the present winter. Whereas its resources are not large, it still has available funds to take care of worthy cases, especially when they happen to be members who reside outside of the larger communities and in places where other forms of relief work are not accessible to them. Members of the Institute who know of other members, or in fact of any worthy cases where engineers are in dire circumstances, are encouraged to make a report of the case to the national secretary, 33 West 39th Street, New York, N. Y.

The relief offered is through the form of loans, in return for which the recipient signs a note which does not bear interest and which does not require any endorsement or the deposit of any collateral.

San Francisco Section Membership Increasing

A pleasing note is contained in a bulletin from the Institute's San Francisco Section received during the month of January that should be encouraging to other Sections and perhaps give a suggestion of the sort of spirit which brings members to the Institute. The bulletin reads as follows:

"During the last 4 months, the San Francisco Section of the A.I.E.E. has added 14 new members, and has 17 new applications on file at Institute headquarters. This represents approximately a $7^1/_2$ per cent increase, right in the middle of the worst depression the world has ever known. It proves that, in the Northern California area at least, engineers have an appreciation of the value of contacts and friendships among men in the same profession."

Annual Meeting of Committee on Illumination

The annual meeting of the United States national committee of the International Commission on Illumination was held in New York, N. Y., November 9, 1932. E. C. Crittenden (A'19, M'22) is president of this committee, and G. H. Stickney (A'04, F'24) is secretary-treasurer. Items of interest taken from the minutes of the annual meeting follow:

Reports of the 27 technical committees showed that many were a little slow in getting started on preparations for the next plenary session of the commission which is to be held in Berlin, Germany, in 1934. Steps were taken to stimulate action.

The I.C.I. committee on aviation, ground lighting, held an international meeting in Zurich, Switzerland, in August 1932, the report of which had just been received and referred to the U.S. representative, F. C. Breckenridge. While the United States was not represented by any individual complete reports were sent to the meeting from this country.

A meeting of the electrical advisory committee of the International committee on weights and measures is to be held at Geneva, Switzerland. Photometric data and proposals have been sent from the United States. The I.C.I. technical committees on standards and units of light have been invited to cooperate. E. C. Crittenden, U.S. representative on these committees, expects to attend.

The officers of the U.S. national committee and the U.S. representatives on the I.C.I. executive committee were reelected. Representatives of the Institute on the committee are A. E. Kennelly (A'88, F'13, Life Member and past-president) and C. H. Sharp (A'02, F'12). All secretariat committees and U. S. representatives on other technical committees were reappointed. E. C. Crittenden replaced the late Dr. C. O. Mailloux (A'84, F'12, Life Member and past-president) as U.S. representative on vocabulary, and L. A. Jones replaced the late Dr. I. G. Priest on colorimetry. The deaths of Dr. C. O. Mailloux and Dr. I. G. Priest were suitably memorialized.

F. C. Breckenridge and C. D. Fawcett (A'14, M'20) directors of secretariats, were elected members-at-large of the national committee.

Arrangement was made for the distribution of the printed Proceedings of the 1931 international congress and of the I.C.I. Proceedings when received.

Reports of Illumination Session Printed—The 1931 session of the International Commission on Illumination was held at Cambridge, England, September 13–19, 1931. Four U.S. secretariat reports presented at these sessions in Cambridge in 1931 have just been received. These are: factory and school lighting, automobile headlights, applications of light, and aviation lighting. It is stated that the complete Proceedings are expected soon. As stated in the report of this illumination congress contained in ELECTRICAL ENGINEERING for January 1932, p. 55–6, complete files of the Proceedings have been placed in the office of the Illuminating Engineering Society, 29 West 39th Street, New York, N. Y., for the use of those who may wish to consult the papers before the Proceedings are issued.

Civil Engineers Hold Annual Meeting

At the annual meeting of the American Society of Civil Engineers held in New York, N. Y., January 18–21, 1933, announcement was made of the election of officers for the year 1933, the men elected taking office immediately.

Alonzo J. Hammond, consulting engineer of Chicago, Ill., was elected president. Mr. Hammond served as a director of the society in 1926–28, and as vice-president in 1929–30.

Vice-presidents elected to serve for 2 years were F. O. Dufour, consulting engineer to the United Engineers and Constructors, Inc., Philadelphia, Pa., and F. G. Jonah, chief engineer of the St. Louis, San Francisco Railway Company, St. Louis, Mo. Directors elected to serve for 3 years were J. P. H. Perry and J. F. Sanborn, both of New York, N. Y., H. J. Sherman, Camden, N. J., R. J. Reed, Los Angeles, Calif., W. W. Horner, St. Louis, Mo., and E. N. Noyes, Dallas, Texas.

The annual awards of the society's prizes and medals were made to the following members: D. L. Yarnell and F. A. Nagler received the J. James R. Croes Medal for

their paper entitled, "Effect of Turbulence on the Registration of Current Meters"; C. A. Betts received the Thomas Fitch Rowland prize for his paper, "Completion of Moffat Tunnel of Colorado"; E. I. Brown, the James Laurie prize for his paper "The Chesapeake and Delaware Canal"; Fred Lavis, the Arthur M. Wellington prize for "Highways As Elements of Transportation"; and A. R. C. Markl, the Collingwood prize for juniors for his paper entitled, "The Shannon Power Development in the Irish Free State."

The American Society of Civil Engineers at its annual meeting also conferred honorary membership on 3 of its distinguished members. These are C. L. Strobel, J. E. Greiner, and Lincoln Bush. Mr. Strobel for many years was active in the design and construction of bridges and other forms of steel work. He was the author, compiler, and editor of the original and several later editions of the Carnegie Handbook. He served as director of the society in 1886 and in 1894, and was vice-president in 1911–12.

Mr. Greiner, a consulting engineer of Baltimore, Md., after a number of years in the service of the Baltimore and Ohio Railroad, entered private practice in 1888, and has been retained as consulting engineer on more than 300 important bridges and other engineering structures. He was a director of the society 1915–17.

Mr. Bush, the third member receiving honorary membership, is a consulting engineer of New York, N. Y. In 1909, after having been bridge engineer and later chief engineer of the Delaware, Lackawanna, and Western Railroad, Mr. Bush became a consulting engineer and contractor, especially in the fields of railroads and bridges. He was a director of the society in 1912–14, treasurer 1915–16, vice-president 1924–25, and president in 1928.

Columbia University Offers E.E. Scholarships

The governing bodies of Columbia University have placed at the disposal of the A.I.E.E. each year, a scholarship in electrical engineering in the school of engineering of Columbia University for each class. The scholarship pays $350 toward the annual tuition fees which vary from $340 to $360, according to the details of the course selected. Reappointment of the student to the scholarship for the completion of his course is conditioned upon the maintenance of good standing in his work.

To be eligible for the scholarship, the candidate recommended will have to meet the regular admission requirements, in regard to which full information will be sent without charge upon application to the secretary of the University, or to the national secretary of the Institute, 33 West 39th St., New York, N. Y.

In a letter addressed to the national secretary of the Institute, an applicant for this scholarship should set forth his qualifications, including age, place of birth, education, reference to any other activities, such as athletics or working way through college, references, and photograph. A committee composed of Messrs. W. I. Slichter, chairman, Francis Blossom, and H. C. Carpenter will consider the applications and will notify the authorities of Columbia University of their selection of a candidate. The last day for filing of applications for the year 1933–34 will be June 1, 1933.

The course at the Columbia school of engineering is a graduate course which may be either elective leading to the degree of master of science or prescribed leading to the degree of electrical engineer. For the former, requirement for admission is the completion of 4 year course in electrical engineering as evidenced by a bachelor's degree from an approved institution. For the professional degree, the requirements are more specific as to course content and include considerable proficiency in mathematics, physics, and chemistry, and some knowledge of the humanities as well as the usual undergraduate technical courses. The candidate is admitted on the basis of his previous collegiate record without undergoing special examinations. Other qualifications being equal, members of the Student Branches of the A.I.E.E. will be given preference.

The purpose of this advanced course is to produce a high type of engineer, trained in the humanities as well as in the fundamentals of his profession. It is hoped that enrolled students and others qualified will show a keen interest in this scholarship.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or to reject them entirely. STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

The Causes of the Present Depression

To the Editor:

There is one characteristic of an engineering paper that is fundamental—the presentation of facts and figures from which the validity of the author's conclusions can be independently judged. An engineer may make predictions, but he should first show that his theory fits all the known facts—he may make assumptions, but not unnecessary ones.

I have been greatly interested in the various economic proposals recently presented in ELECTRICAL ENGINEERING and elsewhere, but I have been disappointed by the general disregard of the above-mentioned principles, your correspondent Mr. Forbes and a few others excepted. We need more and better statistics, and the evaluation of existing theories by their application to known cases; not the revival of threadbare panaceas and repeated statements that a new era has come in which all previous experience is valueless. In economics, as in nature, only destruction is sudden; growth and progress evolve slowly along paths predetermined by facts long recorded for all to see.

There are 2 major ideas that seem just now most popular as explanations of the depression: the existence of profits, and technological unemployment. Also, there are 2 explanations that seem to me most important—the post war deflation to gold prices, and the recent inflation of credit in the United States. My search for facts bearing on these 4 theories has led me to the following:

The claim is made that industrial profits are hoarded, put into new factories, or otherwise withdrawn from purchasing power, so that the difference between the retail prices and total production cost of commodities must be made up by consumer borrowing. Hence the conclusion is drawn that the existence of profits makes the industrial system unstable by building up an unsalable surplus of hats and shoes, as so charmingly explained in the Russian primer. If, however, the profits are immediately used in building schools, roads, and art museums, or to store up durable goods for use in our old age, the system can progress indefinitely. The real need is, therefore, to expand our profits wisely, expanding our factories as required, and in proportion; and putting the surplus into new industries and non-productive capital goods. May not this be done by our present system without government control, for how else have we secured our present standard of living?

From various sources, I have obtained the following approximate figures, in billions of dollars:

Total valuation of all U.S. property, exclusive of land	220
Total net worth, 1931, of 1,620 major U.S. corporations	51
Total profits after taxes of these corporations, 1929. (Profits in 1930 and 1931 were 3.0 and 1.3, respectively.)	5.2
National income, 1926, approximately. (Of this, 45 were salaries and 3 dividends.)	82
Total U.S. taxes of all kinds	12

From these figures, it appears that the total profits of manufacturing, trading, and public utility corporations in the boom year 1929 available for reinvestment were much less than the total of all taxes. Only a fraction of these profits is available for reinvestment in industry, so that they seem quite insufficient to finance unhealthy expansion.

From United States census reports summarized by Warren and Pearson (*Farm Economics*, v. 4, 1932, N. Y. State College of Agriculture, Ithaca, N. Y.), the total basic production in the United States increased in physical volume from 1839 to 1914 at a remarkably steady rate of 4.0 per cent each year, while it rose from 1915 to 1929 at the rate of only 2.1 per cent annually. The per capita figures were only 1.73 and 0.64 per cent, respectively. Thus, the evidence shows an insignificant annual increase in production through the boom period, when ample consumer credit was

available. On the other hand, nearly 1/4 of all production in 1919, and 1/3 in 1929, was of durable goods, indicating that large investments in capital equipment were being made. Most of the savings (and borrowings) must have been used for non-productive equipment, thus indicating the over-savings or profits theory to be of relatively little importance.

During the past half century, while productive power has steadily increased, actual world production of basic materials per capita has risen slightly less than 2 per cent per year, while the percentage of unemployed has not varied materially under comparable credit conditions. In England, for example, the percentage of trade unionists unemployed varied between 3 or less in 1889, 1900, 1906, 1912, and 1914–20, and about 8 in 1887, 1894, 1904, and 1908, although it rose to about 20 in 1921 and 1931 and only fell to 11 in the period 1923–30. In the United States the percentage of unemployed in 1929 was undoubtedly as small as in earlier boom periods, despite technological advances. A review of conditions 60 yr or more ago, when child labor and 12- to 14-hr working days were universal, brings a realization of the great benefits of the machine age. Any future improvement in productivity can be taken care of, as in the past, by shorter working hours and lengthened periods of education and retirement. Thus, technological unemployment appears as a problem of readjustment requiring insurance and compensation laws rather than as a defect of the industrial system.

On the other hand, all history shows that the present depression is a logical aftermath of the tremendous expansion of government bonds and paper money, whereby the war costs were paid. Wholesale commodity prices in the United States rose from 100 in 1910–14 to 226 in 1920, and fell only to about 140 in the 1921–29 period. In other countries, which suffered greater currency inflation, prices rose further and stayed high longer. After the Napoleonic wars and after the Civil War, the price level fell about 50 per cent in 10 yr, in each case to the pre-war level. With a relatively fixed ratio of gold supply to the number of monetary transactions before and after the war, a higher price level could be maintained only by greater efficiency in the use of gold or a revaluation of currencies. When, therefore, in the period 1924 to 1928, the 7 principal European countries successively returned to the gold standard and endeavored to secure gold stocks sufficient to maintain parity of their currencies, the scarcity of gold in relation to the prive level became increasingly evident. Numerous published statistics (See for example p. 1685–99 of *Farm Economics*, v. 4, 1932) show the remarkably close adherence of gold prices to the ratio of monetary gold stocks to volume of production over the past century. Even more numerous articles show the cataclysmic effects on production and employment of the drop to pre-war prices thus made inevitable.

In the United States, particularly, there was a post war overexpansion of credit, as clearly shown by E. C. Harwood (CAUSE AND CONTROL OF THE BUSINESS CYCLES, E. C. Harwood, 1932). The natural fall of commodity prices toward pre-war levels was halted by this inflation, giving a deceptive appearance of stability. As Harwood's index of inflation shows, however, the banks issued some 7 billions of dollars more credit than they had available in sound values, while brokers' loans expanded even more. Much of this credit financed duplication of industrial equipment by mushroom companies which disregarded patents and cut prices below costs, thus stealing the fruits of expensive developments from responsible organizations and ultimately bankrupting both. Realization that the paper values of all sorts of securities were unreal, followed by the demand for gold from abroad, seem to me, therefore, to have been the major causes of our present difficulties.

In conclusion, I wish to heartily recommend the writings of G. F. Warren and F. A. Pearson of Cornell University, that have appeared in many issues of *Farm Economics*, and those of Col. Leonard P. Ayres, as the most sensible and fact-abiding essays of any that I know in this field.

Very truly yours,

P. L. ALGER (A'17, F'30)
(General Electric Co.,
Schenectady, N. Y.)

"Instrumentation" Grows in Importance

To the Editor:

It would seem almost more than a coincidence that a number of the suggestions appearing in Professor Karapetoff's letter in the September 1932 issue of ELECTRICAL ENGINEERING, p. 669, should have found answer in the preface to a contemporaneous volume. I refer to the refreshing little handbook, "Fundamentals of Instrumentation," by M. F. Béhar (Instruments Publishing Company, 1932); and in correlating the 2, I can do no better than quote from the respective authors.

In Professor Karapetoff's letter we find the following statements: "We need several types of middlemen between the pure sciences and the engineering art, and we need them urgently. . . . . An ambitious young engineer with scientific learnings can do no better than to study the fundamental sciences and thus prepare himself for a place of middleman and interpreter in some specific problem of the industry of the future."

As an almost direct answer to this call, I find in the preface to Mr. Béhar's manual the following: "In the pursuit of practical ends many a practical man turns into a research worker; many an engineer with a bent for research turns into an empirical physicist, irresistibly drawn toward pure science. . . . . Not only is the 'pure' harvest of the scientist pounced upon avidly by the practical industrialist; but today the latter plows and reaps and threshes with the former. They greet each other, clasp friendly hands, labor shoulder to shoulder, get to understand each other, begin to talk the same language and end up much alike. Who dares nowadays lay down a dividing line between pure science and industrial instrumentation? . . . . The whole philosophy of measurement and control is so new that the word instrumentation (in its non-orchestral sense) has probably not reached the lexicographers. . . . . but I confidently predict the early recognition of instrumentation as a distinct branch of engineering and as a distinct field of scientific management. I foresee instrument courses in the majority of technical schools, chairs of instrumentation in universities, a nation-wide or international society, an Institute with corporate members, and all the panoply of an established, organized, esteemed profession. These developments must come about, I believe, in order that the benefits of instrumentation may be extended—first throughout the industry and then . . . . . beyond!"

One, at least, of the types of "middlemen" for which Professor Karapetoff calls is undoubtedly the "instrumentician," who in his work strives to link the field of pure science with that of applied engineering principles. Perhaps not so much in electrical and mechanical engineering as in other branches of technical activity has the link been wanting. Our committee on instruments and measurements, a selected group representing all branches of electrical measurement, has long been performing a function of incalculable value to the industry, and an immense variety of problems having to do with the art of measurement are thus taken off the hands of those who are not so much concerned with the actual means of obtaining quantitative measurements as with the use made of values so obtained. And what this committee does for the industry in general, the individual instrumentician does for its component parts.

A glance through the index of an engineering library, or a cursory reading of the technical book reviews shows that, among the volumes dealing with instruments and measurement, there are probably as many on electrical instruments and their uses as on all other types of engineering measurement. The electrical profession has pioneered in the segregation of the art of measurement from other branches of its work; but in the allied fields of engineering there is already noted a growing tendency in the same direction.

In these days when so many of the older engineers have an opportunity to pause and take stock of themselves, and when the younger men are perhaps wondering if a technical training is really worth while, it is fitting that we should take heed to these 2 messages; first, Professor Karapetoff's call for men to fit themselves to fill those gaps between applied engineering and pure science, and then to Mr. Béhar's revelation of the rapidly growing importance of the field of measurement and control.

Very truly yours,

PERRY A. BORDEN (M'19)
(Electrical Engineer,
Box 17, Waterbury, Conn.)

Improving the Institute's Conventions

To the Editor:

The suggestion concerning conventions by K. K. Palueff in ELECTRICAL ENGINEERING for January 1933, p. 58, interested me very much and I hope it will be given serious consideration by our convention committees.

I always have held the "Convention" as one of the major activities of the Institute. I particularly have watched its development since the District convention plan was adopted, for the latter provided the means for presence of the average member, notably those who were unable for various reasons to attend the annual and summer conventions. The present convention plan as a whole provides so that those particularly so desiring can meet informally and also gives the chance to do so for those desiring to attend the sessions and take part actively.

Mr. Palueff courteously makes no reference specifically to the fairly meager amount of time allotted to the sessions out of the total time available, but had he done so, I am sure that a considerably greater amount might be found for the sessions. It further is perfectly possible to have certain of the social events coincide or parallel the technical session.

Personally the opportunity to meet men informally at the convention appeals to my own desires and best permits me to serve the Institute, but I cannot refrain from the highest respect for the member who desires to put his time into the meetings as profitably as he can. His is the hard painstaking method that accomplishes real results and tends to the forward movement and standing of the Institute and where he

takes the time and thought to present his views as does Mr. Palueff, is ample reason to give the same most careful consideration.

Very truly yours,

ARTHUR G. PIERCE (A'08, F'20)
(Manager, Central District, Cutler-Hammer, Inc., Cleveland, Ohio.)

Consumption, Production, Distribution

To the Editor:

I have been greatly interested in the progress report of American Engineering Council ("The Relation of Consumption, Production, Distribution," ELECTRICAL ENGINEERING, June 1932, p. 373–9), and in the allied articles and letters on the subject. It seems an encouraging sign that for the first time, apparently, engineers have turned to the serious consideration of economic engineering. But I am surprised to note the total failure to take into adequate consideration one basic fact, without which all remedies tried or proposed will not in any way eliminate the recurrent distress which is so plainly evident today. That fact is this: the economic gap inherently existing at all times between the producing and consuming powers of the masses. While this fact is apparently discussed under the heading "Apparent Causes of Present Depression" of the above report, it is in reality obscured rather than clarified. It is very self-evident that to make a balanced economy, nationally or internationally, which is the only possible way to avoid cyclical depressions, consumption must keep pace with production so that no surplus accumulation can occur, including within the meaning of consumption the maintenance, reproduction, and extension of plant and an emergency supply of commodities against catastrophes of nature. By way of illustration, if any 100 workers, which by extension means all workers, were engaged in producing crops or goods for themselves, it is evident that if in a given period they produced for example twice as much as in some other equivalent period they would have twice as much and therefore be better off, not worse off as they are now, when producing greater quantities. If such increased production were more than they could consume, the remedy also is self evident, namely to shorten their working time while still having all they could consume. To a man from Mars it would certainly look like insanity for a surplus of all material goods to throw millions out of employment so that they cannot secure any of such goods.

Now self-evidently also the balancing of consumption with production means that the producers must have the wherewithal to secure the production in order to consume it. Otherwise they will be able to consume only a greater or lesser, usually lesser, portion of such production. The unconsumed portion must accumulate or be disposed of elsewhere. Both results happen, part accumulates and part is exported, or worse yet in very acute situations deliberately destroyed, as witnessed by the destruction of coffee in Brazil, plowing under cotton in our own South, and uprooting peach trees in California. When the cyclical depression does not occur simultaneously over the whole world, exports may delay the accumulation in any one country, but eventually it arrives and must arrive. This time, however, the depression is simultaneous throughout the world. We are therefore in the predicament of the Scilly islanders, living by doing each other's wash.

Therefore it seems to me idle to talk about any arrangement of planning, banking, finance, inflation of currency, or any of the other nostrums advanced to overcome this fundamental difficulty, namely, the gap between commodities produced and the purchasing power of the producers. It is inherent in the present method of production and distribution. For an engineer, it would be just as sensible to attempt to work a machine which is supposed to turn out a steady flow of product but which contained an element periodically clogging because of its very construction. Any engineer that deserved the name would immediately redesign the machine to avoid this clogging. Therefore it should be evident to anyone who thinks, instead of repeating cut and dried economic theories, that until the discrepancy between production and consumption is permanently removed, no planning, no shorter hours, no inflated currency, nor any other or all of the proposed remedies can avoid the clogging of the economic machine periodically, because this fundamental cause is left untouched. This depression period is becoming ever more frequent due of course to improved technique. The census figures on the productivity of labor during the past 12 years show this with startling clearness. One method of meeting the depression, shortening hours without reducing real wages, may act as a brake to delay its advent but not avoid it in any way. Shortened hours with proportionately reduced wages is of course absurd, as it changes nothing at all. It merely makes the present employed share his wages with the present unemployed, but adds nothing to the total purchasing power. Planned production, even if it could be enforced, which all of past experience has shown to be impossible, will be no more able to sell its commodities in a market that lacks the wherewithal to buy them than is the present anarchic production.

I have not these figures at hand, but as I remember them they are roughly as follows: total income in the United States in 1929, \$90,000,000,000; total earned income including all salaries large and small, \$48,000,000,000; leaving as a balance \$42,000,000,000 to cover unearned income, profits, interest, and rent. As the latter amount falls into the hands of a relatively small percentage of the population, only a small portion of it can be spent for current consumption and must be used either in new wealth producing means of production (new investment) or exported, both of which eventually bring about the same result. For new construction beyond adequate plant already existing, while temporarily disposing of some of the surplus, simply increases production without increasing consumption proportionately, thereby aggravating the difficulty. Exported capital simply provides production abroad which in turn limits the otherwise possible exports of commodities which might have absorbed another part of the surplus, also aggravating the difficulty.

On the other hand it is clearly evident that if the whole \$90,000,000,000 were earned income, it would necessarily be mass distributed and therefore most of it promptly spent in consuming the production for which it was paid. In effect it would amount to almost doubling everybody's (real) wages without increasing the cost of commodities in any way, and therefore the consumption of such commodities would similarly increase. Instead of a surplus of goods there would be an actual deficiency, thus requiring full time of factories, farms, etc., with more wages, thus repeating the process. There could be no surplus accumulation until everybody had everything they wanted (if such a state could ever arise), when shortened hours without reduction of purchasing power would settle any question of surplus.

I would be glad to see engineers make some concrete suggestions as to how the gap between production output and the consuming power of the masses can be closed.

Very truly yours,

CARROLL SHIPMAN (M'08)
(Consulting Engineer, Holbrook Building, San Francisco, Calif.)

Synchronizing Torque of An Unexcited Salient Pole Motor

To the Editor:

Recently I had been searching for a formula to calculate the synchronizing torque exerted by a sinusoidal polyphase rotating field on an unexcited salient pole secondary member, rotating synchronously, and did not find any such information. Consequently, I worked out this case in the manner indicated in the following paragraphs; results of theoretical investigation agree exactly with several machine tests.

The air-gap under the salient pole is considered to be uniform, and the air-gap in the interpolar zone also is considered to be uniform; infinite permeability is assumed in iron paths.

LIST OF SYMBOLS USED (See Fig. 1)

- α = $\dfrac{\text{pole arc}}{\text{pole pitch}}$
- τ = pole pitch in cm
- δ_1 = air-gap in cm between salient pole and primary member
- δ_2 = air-gap in cm between interpolar space and primary member
- B_m = maximum air-gap induction in lines per sq cm under salient pole
- b_m = maximum air-gap induction in lines per sq cm in interpolar space
- l = axial iron length in cm
- p = number of poles
- x = distance in cm from origin
- E = energy in cm-kg stored in air-gap
- F = force in kg at center of air-gap (tangential component)
- r = radius of center line of air-gap in cm
- T = synchronizing torque in cm-kg

The magnetic energy in cm-kg per cm² = $(\delta/24.6)\ (B_x/1000)^2$. The total energy in the air-gap in cm-kg is given by the formula

$$E = \frac{lp\delta_1}{24.6}\left(\frac{B_m}{1000}\right)^2 \int_{x_1}^{x_1+\alpha\tau} \sin^2\frac{\pi x dx}{\tau} + \frac{lp\delta_2}{24.6}\left(\frac{b_m}{1000}\right)^2\left(\int_0^{x_1}\sin^2\frac{\pi x}{\tau}\,dx + \int_{x_1+\alpha\tau}^{\tau}\sin^2\frac{\pi x}{\tau}\,dx\right) \qquad (1)$$

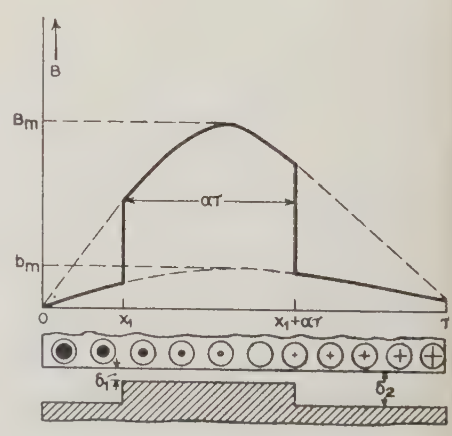

Fig. 1

Integrating

$$E = \frac{lp\delta_1}{24.6}\left(\frac{B_m}{1000}\right)^2 \left\{\frac{x_1 + \alpha\tau}{2} - \frac{x_1}{2} - \frac{\tau}{4\pi} \sin\left[\frac{2\pi(x_1 + \alpha\tau)}{\tau}\right] + \frac{\tau}{4\pi}\sin\frac{2\pi x_1}{\tau}\right\} + \frac{lp\delta_2}{24.6}\left(\frac{b_m}{1000}\right)^2 \left\{\frac{x_1}{2} - \frac{\tau}{4\pi}\sin\frac{2\pi x_1}{\tau} + \frac{\tau}{2} - \frac{\tau}{4\pi}\sin 2\pi - \frac{x_1 + \alpha\tau}{2} + \frac{\tau}{4\pi}\sin\left[2\pi\frac{(x_1 + \alpha\tau)}{\tau}\right]\right\} \quad (2)$$

The force in kilograms to move the salient pole relative to the field is equal to dE/dx; then

$$F = \frac{dE}{dx} = \frac{lp\delta_1}{24.6}\left(\frac{B_m}{1000}\right)^2 \frac{1}{2}\left(\cos\frac{2\pi x_1}{\tau} - \cos 2\pi\alpha \cos\frac{2\pi x_1}{\tau} + \sin 2\pi\alpha \sin\frac{2\pi x_1}{\tau}\right) + \frac{lp\delta_2}{24.6}\left(\frac{b_m}{1000}\right)^2 \frac{1}{2}\left(-\cos\frac{2\pi x_1}{\tau} + \cos 2\pi\alpha\cos\frac{2\pi x_1}{\tau} - \sin 2\pi\alpha \sin\frac{2\pi x_1}{\tau}\right)$$

Now, $b_m = \frac{\delta_1}{\delta_2} B_m$

Hence

$$F = \frac{lp\delta_1}{24.6}\left(\frac{B_m}{1000}\right)^2 \left(1 - \frac{\delta_1}{\delta_2}\right)\frac{1}{2}\left(\cos\frac{2\pi x_1}{\tau} - \cos 2\pi\alpha\cos\frac{2\pi x_1}{\tau} + \sin 2\pi\alpha \sin\frac{2\pi x_1}{\tau}\right) \quad (3)$$

It can be shown that the maximum force occurs when the center line of the salient pole is moved $\pi/4$ radians from the center line of the maximum gap density, i. e., when $x_1 = (3\tau/4) - (\alpha\tau/2)$; substituting this value in eq 3

$$F_{max} = \frac{lp\delta_1}{24.6}\left(\frac{B_m}{1000}\right)^2 \left(1 - \frac{\delta_1}{\delta_2}\right)\frac{1}{2} (\cos 2\pi\alpha \sin \pi\alpha - \sin\pi\alpha - \sin 2\pi\alpha\cos\pi\alpha) = \frac{lp\delta_1}{24.6}\left(\frac{B_m}{1000}\right)^2 \left(1 - \frac{\delta_1}{\delta_2}\right)\sin\pi\alpha \quad (4)$$

The maximum torque in cm-kg will be $F_{max}r$. From eq 4 the following is deduced: If $\delta_1 = \delta_2$, $F = 0$ because we have a uniform cylindricular rotor; if $\alpha = 0$, or $\alpha = 1$, $F = 0$ for the same reason. For maximum torque, choose $\alpha = {}^1/_2$. As large an air-gap as permissible from heating and other considerations is necessary to obtain the limiting force that a particular frame is capable of withstanding. The torque varies as the square of air-gap induction, hence the flux density should be large.

Very truly yours,
R. D. BALL (A'31)
(English Elec. Co., Bradford, England)

Distribution of Employment

To the Editor:

The present scarcity of employment has produced a situation in the field of engineering as well as in other fields that to say the least is an oddity even though orthodox. The number of men employed in engineering has probably been reduced proportionately more than in any other profession. At the present time one who is not employed is very apt to find it almost impossible if not impossible to earn a living and yet men who have had the higher salaried positions for a long time and who in all reasonableness should have a fairly large amount of reserve wealth are retained by employers while lower salaried men, often younger, are released. If there were a shortage of capable men for these higher positions, (and generally speaking there is not) or if there were a prospect of suddenly needing a large engineering force and the key men of the organization were retained as a nucleus, such conditions might be justified, but in a great many cases, probably in the majority of them, retaining these men is not so justified.

Men with individual fortunes who might well retire usually choose to remain employed and are often retained by the employer at a salary which is large enough that it might be distributed among 2 or more former employees of sufficient ability and experience to handle the comparatively unimportant work generally encountered at present. In a great many engineering offices the only men still employed are former department heads and executives who are receiving a comparatively high salary and are doing work of a very minor character. If these men have enough wealth accumulated to retire on, and what constituted a small fortune prior to 1929, will now make a very sizable one if it didn't shrink with the security market, why should not they do so or at least accept a salary commensurate with the work they are now doing and make room for some of their less fortunate former colleagues?

Very truly yours,
ELLERY R. FOSDICK (A'26)
(825 Trent Avenue, Spokane, Wash.)

American Engineering Council

Annual Meeting and Election of Officers

The assembly of American Engineering Council held its annual meeting in Washington, D. C., January 13–14, 1933. The meeting was attended by more than 50 representatives of the engineering societies which comprise American Engineering Council. Representatives of the A.I.E.E. who were in attendance at the meeting were C. O. Bickelhaupt, F. J. Chesterman, H. H. Henline, W. S. Lee, L. F. Morehouse, I. E. Moultrop, Farley Osgood, C. E. Skinner, and L. B. Stillwell.

ELECTION OF OFFICERS

Vice-presidents elected at this meeting to serve for the 2-year term, 1933–34, are John F. Coleman of New Orleans, La., member of the engineers advisory board of the Reconstruction Finance Corporation and a past-president of the American Society of Civil Engineers, and William H. Woodbury of Duluth, Minn., past-president of the Minnesota Federation of Architectural and Engineering Societies. FARLEY OSGOOD (A'05, F'12, past-president) of New York, N. Y., was reelected treasurer for the term of one year, and A. J. Hammond, president of the American Society of Civil Engineers was reelected chairman of the finance committee. W. S. LEE (A'04, F'13, past-president) of Charlotte, N. C., continues as president, having been elected a year ago for the term of 2 years. Gen. R. C. MARSHALL, Jr., and L. B. STILLWELL (A'92, F'12, past-presidents) both of New York, N. Y., continue as vice-presidents. Representatives of the Institute on Council's administrative board for 1933 are C. O. Bickelhaupt, H. P. Charlesworth, F. J. Chesterman, C. E. Skinner, and C. E. Stephens.

TECHNOCRACY CRITICIZED

Resolutions relating to Technocracy were adopted by Council at its annual meeting, the text of the resolutions being as follows:

"The statements of a group of men organized under the name 'Technocracy' have received wide publicity through the press by reason of startling predictions which involve a complete overturn in our economic structure. These pronouncements, circulated as coming from engineers, have led to the belief that they represent responsible engineering thought.

"Many requests for information on Technocracy have come to American Engineering Council, which is the representative of national, regional, and local engineering societies in the United States. The Council has endeavored to obtain from the promoters of the movement an authoritative statement of their findings and their program. It is significant that no information could be obtained beyond what has appeared in the press.

"The accepted practice among engineers of presenting new developments to some engineering society for critical study and discussion has not been followed. The data and statistics brought forward in magazine and newspaper articles as a basis for speculative claims are open to question; some of the findings have been discredited or disproved by other investigations.

"These statements and conclusions may have the serious effect of undermining public confidence in our present civilization; and they hold out an unwarranted promise of a quick solution of economic ills. The method of presentation has been marked by exaggerated, intolerant, and extravagant claims. They have capitalized the fears, miseries, and uncertainties due to the depression and have proposed a control which is, in effect, class dictatorship.

"Contrary to these claims, there is nothing inherent in technical improvement which entails economic and social maladjustments. Indeed technology offers the only possible basis for continuing material progress. The volume of goods produced, distributed, and consumed during the years 1928 and 1929 was not excessive. That volume may and should be surpassed upon the return of prosperity.

"The alleged unmanageability of a machine economy has not been proved. Its dislocations are traceable to improper and unskilled use rather than to inherently harmful characteristics. Complete replacement of men by the machine is precluded by the law of diminishing returns. Instances are increasingly in evidence. Contrary to the pronouncements of Technocracy, applied science holds the promise of better things to come in a society which fearlessly and intelligently meets its prob-

lems. It is the considered opinion of American Engineering Council that our present economic structure contains within itself the possibilities of progressive improvement and of the attainment of higher standards of living."

Proposed Modifications of Relief Act

The Council adopted the report of the committee on government expenditures recommending modification of the emergency relief and construction act of 1932. The report recommended that Congress liberalize the act by removing both the self-liquidating stipulation, and the restriction relative to taxation in section 201 of Title II, authorizing loans by the Reconstruction Finance Corporation to states, municipalities, and other agencies to aid in financing self-supporting projects. These projects, it was suggested, should be limited to those which are needful and economically sound. Greater discretion, it was felt, should be vested in the directors of the corporation.

The Council recommended reduction of the interest rates on loans, and also advocated an increase in the kinds of work devoted to public use which are eligible for loans.

Government Reorganization Discussed

A report was submitted by Council's committee on administration of public works outlining the status of the present effort to effect a reorganization of the federal agencies. A recommendation was adopted that effort be made to bring the views of Council on this subject to the attention of President-Elect Roosevelt and the new federal administration.

Other Actions Taken

The Council also passed a resolution praising the services of President Hoover, who was the Council's first president.

The assembly approved the recommendation of Council's committee on water resources, which among other things recommends studies looking into the ultimate establishment of a bureau of water resources within the proposed division of public works of the United States Government, wherein will be coordinated as far as feasible activities relating to water resources.

Various committees reported to the assembly as to the features of pending or proposed congressional legislation of interest to engineers.

The assembly also adopted resolutions and policies on several important phases of public affairs having engineering interest. The appointment of a special committee also was authorized to consider problems relating to tax policies.

The assembly considered a report of a subcommittee relative to legislation for regulation of interstate commerce and adopted the following resolution:

"Whereas, our national system of transportation comprises railroads, highways, pipe lines, waterways, and airways, and

"Whereas, the only present federal regulation of such transportation is that of the Interstate Commerce Commission over the railroads, therefore

"Be It Resolved, that American Engineering Council favors the general principle of extending equitable government regulation to cover all forms of interstate transportation."

The assembly adopted a recommendation that the second progress report of Council's committee on economic balance be made available for publication and distribution.

Federal Power Commission Issues Annual Report.—On November 28, 1932, the federal power commission issued a memorandum summarizing its annual report and reproducing a section of that report in which the commission proposes certain changes in the federal water power act. Control of holding companies having relations with licensees of the federal power commission and a more precise definition of the commission's powers over rates, services, and securities of licensees, as well as extension of authority for cooperation with the states in regulating the interstate transmission of power, are among the proposals made. It was stated that while the commission has given considerable thought to the questions of regulating the interstate power and holding companies in the entire electric utility industry, it has confined its recommendations on these subjects to involve only its own licensees. The commission stated that it is prepared to present to the appropriate committees of Congress upon request specific suggestions as to the amendments proposed, or even preliminary drafts thereof, for the purpose of a more concrete presentation of its ideas.

Engineering Foundation

Plastic Flow of Concrete

Need for more extensive and precise experimental information on the physical behavior of concrete grew out of the arch dam investigation undertaken by a committee of the Engineering Foundation. By request of this committee, a research was undertaken by Prof. Raymond E. Davis in the civil engineering laboratory of the University of California several years ago. It is a long-time study and is yielding data that will be useful not only for arch dams and other types of dams, but also for bridges and other structures.

Professor Davis in the following paragraphs from a letter dated November 9, 1932, indicates the lines along which the research will be pursued during the year 1933:

"As I think I stated in a previous letter, we are this year extending this investigation to include flow of concrete under biaxial and triaxial loading conditions, such as occur in thick dams, arches, and certain other structures. We believe that the information which we will ultimately secure will be of even greater importance to structural design than have been the data having to do with flow under axial stress alone which we have secured during the past few years.

"We are very grateful to Engineering Foundation for the funds which have made possible the pursuit of these investigations, for had it not been for this financial support we should have found it necessary to abandon the project. The value of these investigations has been recognized by others, and I am pleased to say that substantial contributions for carrying on this work during the present year have been made by the research board of the University of California and by the U.S. Government in connection with the Hoover dam. In this respect your continued cooperation during another year seems to be a vital necessity, particularly as the new series of investigations under biaxial and triaxial loading conditions will not have reached a stage where definite conclusions can be drawn before next fall."

Personal

W. F. Sims (A'30, M'26) has been appointed electrical engineer of the Commonwealth Edison Company, Chicago, Ill., to succeed the late R. F. Schuchardt (A'03, M'09, F'12, and past-president) who died in Boston, Mass., October 25, 1932. Mr. Sims was born at Green Bay, Wis., in 1875 and graduated from Armour Institute of Technology in 1897 with the degree of B.S. in E.E., receiving the degree of E.E. in 1903. From 1897 to 1901 he was in the engineering department of the Chicago Telephone Company, and from 1901 to 1906 in the engineering department of the Chicago Edison Company. From 1907 to 1911 he was field engineer, board of supervising engineers, of the Chicago Traction Company, in charge of all supervision of overhead and underground electrical work. Between 1911 and 1915 he was with the Stone and Webster Engineering Corporation, Boston, Mass., in charge of construction and appraisal of public utility systems in various parts of the country. After a year with W. M. McMunn, consulting engineer, Chicago, Ill., on design and installation of small power stations, he joined the Commonwealth Edison Company of Chicago, as field engineer, inside plant division, in 1916. Here he was in charge of engineering of the electrical portion of the main generator station, also having general supervision of the installation of electrical equipment. Mr. Sims subsequently became engineer of inside plant, retaining this position until July 1932, at which time he was appointed assistant electrical engineer in charge of design. Mr. Sims served the Institute on its power generation committee between 1927 and 1931, and is now chairman of the electrical apparatus national committee of the National Electric Light Association. He is also a member of the Western Society of Engineers, and the Naval and Military Order of the Spanish American War.

PHILIP SPORN (A'20, M'26, F'30) electrical engineer of the American Gas and Electric Company, New York, N. Y., has been appointed chief engineer in charge of both the electrical and mechanical engineering activities of the company and its subsidiaries. He was born in Austria in 1896, graduated from the School of Engineering, Columbia University, New York, N. Y., in 1917 with the degree of electrical engineer, and undertook post-graduate work until 1918. Between 1917 and 1919 he was with the Crocker-Wheeler Manufacturing Company, Ampere, N. J., engaged in tests and investigations. In 1919 and 1920 he was electrical designer and technical assistant for the Consumers Power Company, Jackson, Mich. In 1920 he joined the organization of the American Gas and Electric Company in New York, being engaged in various capacities including assistant electrical engineer until 1927, and from 1927 until the present change, chief electrical engineer in charge of electrical design, construction, and electrical operations over the entire American Gas and Electric Company system. Mr. Sporn long has been active in the Institute, having been a member of the technical committee on power transmission and distribution, 1927–28, 1929–33, and research 1932–33. He has presented many papers before the Institute. He is a member of the National Electric Light Association, the Association of Edison Illuminating Company, and the Franklin Institute, and is a fellow of the American Association for the Advancement of Science.

E. E. GILBERT (A'03) sales manager of the turbine department of the General Electric Company, Schenectady, N. Y., retired January 1, 1933, after more than 43 years of service with this company and its predecessor the Thomson-Houston Electric Company. Mr. Gilbert graduated from Rose Polytechnic Institute, Terre Haute, Ind., in 1889, at which time he began work as a test man for the Thomson-Houston Electric Company at Lynn, Mass. He has directed turbine sales for the General Electric Company for the last 30 years.

F. M. CRAFT (A'24, M'27) announced on p. 61 of ELECTRICAL ENGINEERING for January 1933 as having been nominated to serve the Institute as a vice-president representing the Southern District (No. 4) was incorrectly listed in that item as "a director of American Engineering Council and of the Atlanta Chamber of Commerce," whereas he should have been designated, among other things, as "director of the Engineering Council of the Atlanta Chamber of Commerce."

B. G. JAMIESON (A'08, M'17, F'22) who previous to 1929 was engineer of inside plant, Commonwealth Edison Company, Chicago, Ill., now is foreign correspondent of this company, his permanent address now being 4 Place de la Concorde, Paris, France. Mr. Jamieson served the Institute as vice-president, 1926–28, and on the following committees: protective devices, 1922–25, 1928–29; standards, 1923–29; Edison Medal, 1926–28; and electrical machinery 1928–29.

RALPH KELLY (A'12) formerly southwestern district manager with headquarters in St. Louis, Mo., for the Westinghouse Electric & Manufacturing Company, has been appointed central district manager for this company with headquarters in Pittsburgh, Pa. Except for a period of 3 years during the war when he was a commissioned officer in the Navy, Mr. Kelly has been associated with the Westinghouse company since 1909.

G. M. ARMBRUST (A'11, M'22) formerly engineer in the electrical engineer's office of the Commonwealth Edison Company, Chicago, Ill., and since July 1932 system development engineer for this company, now has become assistant electrical engineer in charge of design. He takes the place of W. F. SIMS (A'20, M'26) recently appointed electrical engineer of the Commonwealth Edison Company.

W. POOLE DRYER (A'12) formerly mechanical engineer with Stone and Webster, Inc., Boston, Mass., is now a member of the staff of Arthur L. Nelson Engineers, power plant consultants, of Boston. During the past year Mr. Nelson has been a member of the Institute's power generation committee and chairman of the subcommittee on steam-electric station design.

K. E. V. HALLAR (A'31) previously assistant electrical engineer with The Western Massachusetts Companies, Springfield, Mass., has joined the Husgarna Vapenfabriks AB., Huskvarna, Sweden, as an engineer in charge of the accumulating range department.

L. W. NICKEL (A'17, M'29) formerly with the McGraw-Hill Company as district manager of *Electrical World* and *Electrical West* with headquarters at Cleveland, Ohio, is now editor of *Nema Survey* published by the National Electrical Manufacturers Association, New York, N. Y.

C. H. HOLLADAY (A'21) formerly research engineer for the Southern California Edison Company, Los Angeles, Calif., is now budget engineer for the Los Angeles Railway Corporation. He graduated from the engineering school of Harvard University with the class of 1920.

W. B. SHIRK (A'20, M'32) has recently joined the lubricating sales department of the Gulf Refining Company, Pittsburgh, Pa. Mr. Shirk formerly was steel mill engineer for the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

A. L. RUSSELL (A'30) is head of the electrical department of Franklin Union, Boston, Mass. He previously had been an assistant professor of electrical engineering at Massachusetts Institute of Technology, Cambridge, Mass.

H. E. WULFING (M'23) formerly an engineer for the Commonwealth Edison Company, Chicago, Ill., now has become system development engineer to succeed G. M. ARMBRUST (A'11, M'22).

P. F. WILLIAMS (A'07) formerly engineer of distribution, Commonwealth Edison Company, Chicago, Ill., is now assistant electrical engineer in charge of field engineering for this company.

CLINTON CATER (A'27) formerly of Bude, North Cornwall, England, has recently become assistant engineer of Ceara Tramway, Light & Power Co., Forteleza, N. Brazil.

Obituary

JOHN JOSEPH CARTY (A'90, M'03, F'13, HM'28, past-president and Member for Life) retired vice-president of the American Telephone and Telegraph Company, New York, N. Y., died of cardiac complications at The Johns Hopkins Hospital, Baltimore, Md., December 27, 1932. He was buried with military honors in Arlington National Cemetery, December 29, 1932. Born in Cambridge, Mass., in 1861, he attended high school in that city. Although he never attended college he secured a tremendous source of knowledge through original research, practical experience, scientific reading, and asking questions. In 1879 he entered the employ of the Telephone Dispatch Company of Boston, Mass., where his natural aptitude for mechanics and his love for scientific investigation attracted him to the technical side of the telephone business. Here he developed rapidly and contributed many important advances in the art of telephony. In 1887 he was placed in change of the cable department of the Western Electric Company in the East, and later of the switchboard department, making many improvements in the design and installation of telephone cables and switchboards, including a fundamental invention upon which is based the common battery switchboard subsequently placed in almost universal use. In 1889 Mr. Carty went to the New York Telephone Company, then known as the Metropolitan Telephone and Telegraph Company, as electrician; later he was made chief engineer of this company. Under his direction the technical foundation for the comprehensive New York telephone system was established. In 1907 he became chief engineer of the American Telephone and Telegraph Company, and held this position until 1919 when he was elected vice-president of the American Telephone and Telegraph Company, and placed at the head of the department of development and research. During 1925 the Bell Telephone Laboratories, Inc., was incorporated and Mr. Carty became chairman of its board of directors. He retired in 1930. Among the many important advances made toward the realization of universal service in the telephone system was the completion under his leadership in 1915 of the transcontinental telephone line. Another was the

completion of the Boston to Washington underground cable system, 450 miles in length and then by far the longest underground cable system in existence. A successful demonstration of wireless telephony was made under his direction in 1915. The part played by Mr. Carty in the World War, from which he emerged as a brigadier-general in the United States Signal Reserve Corps., is outstanding. Previous to the entrance of the United States into the war he had planned a mobilization of communication forces and was called into active service 2 weeks after the country entered the war. Four months later he was promoted to colonel in the Signal Corps of the U.S. Army. He was in France for 10 months serving in addition to many other duties as consulting engineer for the Signal Corps of the American Expeditionary Forces, directing the construction of a long distance telephone system covering most of France. His accomplishments in connection with transatlantic communication and the use of secret codes was of tremendous importance. While in France he received the Distinguished Service Medal from the hands of General Pershing. He also was honored by the French government, being made an officer of the Legion of Honor The Emperor of Japan has decorated him with the Imperial Order of the Rising Sun and the Order of Sacred Treasure. Twice the Imperial government of Japan has extended him its formal thanks for his service in connection with the establishment and development of the telephone system in Japan. He received the honorary degree of doctor of engineering from Stevens Institute of Technology, 1915, and from New York University, 1922; the degree of doctor of science from the University of Chicago, 1916, Bowdoin College, 1916, Tufts College, 1919, Yale University, 1922, and Princeton University, 1923; and the degree of doctor of laws from McGill University 1917, and the University of Pennsylvania 1924. In 1903 the Franklin Institute awarded him the Edward Longstreth Medal of Merit for his engineering work, and in 1916 presented him with the Franklin Medal, the highest honor bestowed by this institution. The A.I.E.E. awarded him the Edison Medal in 1918, and in 1928 he was presented the John Fritz Medal, an honor awarded by 4 national engineering societies. Mr. Carty had long been active in the Institute, serving as president for 1915–16. He was a former president of the New York Electrical Society, a fellow of the American Academy of Arts and Sciences and of the New York Academy of Sciences, and a member of the National Academy of Sciences, the National Research Council, the American Association for the Advancement of Science, the American Philosophical Society, the Society for the Promotion of Engineering Education, the American Physical Society. He was an honorary member of the Franklin Institute, and was a member of the Iota Alpha and Sigma Xi honorary societies. He was a trustee of Carnegie Institution, Washington, D. C., the Carnegie Corporation of New York, and Rollins College, Winter Park, Fla. His clubs included the Century, Lotos, Engineers', University, and Railroad Clubs of New York, N. Y., the St. Botolth Club of Boston, Mass., and the Engineers Club (honorary` of Dayton, Ohio).

Edwin Musser Herr (A'07, M'21) vice-chairman of the Westinghouse Electric and Manufacturing Company, New York, N. Y., died December 24, 1932, at his home in New York. In addition to being vice-chairman of the board of directors of Westinghouse, Mr. Herr at the time of his death also was a director in the American Manufacturers Export Association, the Radio Corporation of America, Westinghouse Air Brake Company, and many other organizations. Mr. Herr was born in Lancaster, Pa., in 1860. He graduated in mechanical engineering from Sheffield Scientific School of Yale University in 1884, later receiving honorary degrees of master of arts from Yale University in 1915, and doctor of science from Franklin and Marshall College in 1911. Between 1886 and 1890 he was superintendent of telegraph and division superintendent for the Chicago, Burlington, and Quincy Railroad, Aurora, Ill. In 1891 he was division master mechanic of the Chicago, Milwaukee, and St. Paul Railroad, in 1892 and 1893 he was general superintendent of the Grant Locomotive Works, Chicago, Ill., in 1894 general manager of the Gibbs Electric Company, Milwaukee, Wis., in 1895 assistant superintendent of motive power, Chicago and Northwestern Railway, and in 1896 to 1898 superintendent of motive power for the Northern Pacific Railway. In 1898 George Westinghouse asked him to accept the position of general manager of the Westinghouse Air Brake Company, which position he held until becoming first vice-president and director of the Westinghouse Electric and Manufacturing Company in 1905. This position he held until 1911 when he became president and director. Mr. Herr resigned this position in 1929 to become vice-chairman. He also had been director and officer in a number of other companies. Deeply interested in education, Mr. Herr in 1920 was elected a member of the Yale Corporation and later was appointed to the prudential committee in charge of financial matters connected with Yale University; he also was a member of the corporation's committee on educational policy. Mr. Herr was a member of the Franklin Institute, Pan-American Union, National Industrial Conference Board, American Committee of the International Chamber of Commerce, American Manufacturers Export Association, Historical Society of Pennsylvania, and the board of Carnegie Institute of Technology. He was a member of many clubs in New York, N. Y., and Pittsburgh, Pa.

Horace Field Parshall (A'88, M'90, F'13 and Member for Life) formerly consulting engineer, London, England, and later retired and living at Basses-Pyrenees, France, recently died at the age of 67. He was born at Milford, N. Y., and received the degree of master of science from Lehigh University and that of doctor of science from Tufts College. He was first associated with the Sprague Electric Railway and Motor Company, being responsible for testing and electrical calculation on motors. Doctor Parshall also was associated with Thomas A. Edison and with the General Electric Company, in this country. Since going to London, England, in 1893, he had acted as consulting engineer for various enterprises in Great Britain and on the continent. He was chairman of the board of directors and former executive head of the Central of London Railway, the first modern underground subway in London. As consulting engineer to the contractors of the Central of London Railway he successfully overcame opposition to his ideas, insisting upon the introduction of multiphase generation and transmission, and the rotary converter system. He designed the installation for the Lancashire Electric Power Company, of which he was chairman, and had acted as consultant for the Barcelona (Spain) Traction Light and Power Company, and had designed the dams at Tremp and Camarasa in Spain. Several prizes and medals had been awarded him for his outstanding accomplishments.

Frank Beverley Lamb (A'23, M'26) treasurer of the West Virginia Engineering Company, Charleston, W. Va., died December 21, 1932. Mr. Lamb has been consulting engineer of the firm. He was born in Charles City County, Va., in 1888. After receiving the degree of B.S. in E.E. from Virginia Polytechnic Institute, he spent the years 1910 to 1912 on the practical course at the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. Between 1912 and 1915 he was employed by the Westinghouse company, and was given outside consignments: the first part of this period he was engaged in testing coal mining power plants in West Virginia for the Virginian Power Company, the latter part of this period being commercial manager of the Virginian Power Company (subsequently the Appalachian Power and Light Company) and the Tug River Power and Kentucky River Companies (subsequently the Kentucky and West Virginia Power Company). Since 1915 he has been a member of the firm of the West Virginia Engineering Company. This company is regularly retained as consulting engineers for a great many coal companies in Virginia, West Virginia, Tennessee, and Kentucky, and also does a large part of the electrical construction work for the coal mines in these states. It also controls and manages a number of utilities in which Mr. Lamb had been a director and officer.

William Henry Patchell (A'05, M'06, F'13) consulting engineer, Beckenham, Kent, England, died November 24, 1932. He was born in Lincolnshire, England, in 1862, and received most of his education by private tuition. After an engineering apprenticeship of 5 years and subsequent employment of 3 years by Messrs. Rober and Company, Lincoln, England, both in Spain and in England, he joined the staff of the Electrical Power Storage Company, Millwall, in 1886, being appointed works manager the same year. In 1893 he was appointed engineer-in-chief of the Electricity Supply Corporation, subsequently called the Charing Cross West End and City Electricity Supply Co., Ltd., London. In 1906 he resigned this position and commenced practice as a consulting electrical and mechanical engineer, specializing in application of electricity to mines. In recent years

he has done much to make British engineers better acquainted with the advances in the design and construction of power plants in the United States. Mr. Patchell was a past-president of the Institution of Mechanical Engineers, a past vice-president of the Institution of Electrical Engineers, and a member of the Institute of Civil Engineers.

Local Meetings

Future Section Meetings

Boston

Feb. 14—Mercury Turbine.
March 14—Fuses.

Cleveland

Feb. 16—Communications.
March 16—Some Electric Elevator Problems, by D. L. Lindquist, Otis Elevator Co.

Detroit-Ann Arbor

Feb. 14—at Detroit Edison Auditorium. Hydroelectric Development and Its Present Status in the Industry, by E. M. Burd, The Consumers Pwr. Co.
March 21—Modern Theories of the Composition of Matter, by Prof. A. H. Compton, Univ. of Chicago.

Fort Wayne

Feb. 14—at Chamber of Commerce Auditorium. Travel in the Orient, by Dr. W. K. Hatt, Purdue Univ.
March 14—Modern Methods and Equipment for Power Supervision, by G. A. Grimm, Indiana Serv. Corp.; Some Modern Protective Relays, by V. Verrall, Genl. Elec. Co.

Lehigh Valley

Feb. 10, at Hotel Bethlehem—Storms, Their Effect on and Method of Handling by Large Electric Power and Communication Companies, by E. F. DeTurk, Metropolitan Edison Co.

Pittsfield

Feb. 7—Magic of the Ages, by Dr. Harlan Tarbell.
Feb. 21—Applied Genetics: Directed Evolution, by Dr. Hubert Goodale.
March 7—Experiences of a Gang Buster, by Capt. C. W. Willemse.

Toronto

Feb. 10—Speaker, Dr. J. O. Perrine.
Feb. 24.—Air Conditioning.
March 10—Erection of Large Synchronous Generators, by F. Hoffmeister.

Past Section Meetings

Akron

Some Problems Which Have Troubled Us and Their Remedies, by A. F. Puchstein, Robbins & Meyers Co.; Economic and Commercial Problems Involved in Manufacturing and Selling Fractional Horse-Power Motors, by R. N. Jessop, Ohio Elec. Mfg. Co. P. H. Rutherford, Delco Products Corp., discussed the different types of motors used in the refrigeration industry. Dec. 13. Att. 40.

Boston

Lightning Arresters, by T. H. Haines and C. A. Corney, both of the Edison Elec. Illum. Co. Film—"Artificial Lightning." Dec. 13. Att. 75.

Chicago

Recording Devices and Their Application to Analysis of Power System Disturbances, by A. J. Krupy, Commonwealth Edison Co. Dec. 13. Att. 70.

Cincinnati

Progress Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. Joint meeting with A.S.M.E. Section and Cincinnati Engineers' Club. Dec. 7. Att. 300.

Cleveland

Submarine Treasure Hunting With Underwater Lamps, by E. W. Beggs, Westinghouse Lamp Co. Joint meeting with I.E.S. Dec. 15. Att. 175.

Columbus

Progress Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. Dinner. Dec. 9. Att. 215.

Connecticut

Electrification of Ships, by Capt. Q. B. Newman, U. S. Coast Guard. Dinner. Dec. 13. Att. 52.

Dallas

Today's Problems in Vertical Transportation, by J. L. Zeeryp, presented by G. Humphreys, Otis Elevator Co. Dec. 19. Att. 31.

Detroit-Ann Arbor

Electric Motors and Their Application, by A. M. Dudley, Westinghouse Elec. & Mfg. Co. Illus. Dec. 13. Att. 80.

Fort Wayne

Demand, Its Measurement and Use, by H. M. Witherow, Genl. Elec. Co.; Equivalent Circuit of Static A-C Apparatus With Movable Secondaries, by M. L. Schmidt, Genl. Elec. Co. Dec. 7. Att. 30.

Houston

Vectors and the Engineer, by Prof. M. C. Hughes, Texas A. & M. College. Dinner. Dec. 20. Att. 14.

Indianapolis-Lafayette

The Oscillograph—A Modern Tabloid Reporter, by Prof. G. V. Mueller, Purdue Univ. Dinner. Dec. 9. Att. 88.

Kansas City

Benefits of Technical Societies, by N. W. Downs, chmn., A.S.M.E. Section; Human Engineering, by Rowe Bartle, Kansas State Council of Scouts. Joint meeting with A.S.M.E. Section. Dec. 1. Att. 133.
Household Magic, by W. D. Galpin, Genl. Elec. Co. Films—"Making the Living Room More Livable" and "The World of Tomorrow." Dec. 16. Att. 35.

Lehigh Valley

Three Years Progress in Field Investigation With Artificial Lightning, by K. B. McEachron, Genl. Elec. Co.; Reversed Refrigeration for House and Water Heating, by G. Wilkes, W. S. Barstow & Co. Dec. 9. Att. 127.

Los Angeles

A Trip Around the World, by F. L. Washburn. Dinner. Dec. 13. Att. 48.

Louisville

H. E. Campbell, radio engr., station WHAS, outlined the essential parts of broadcasting equipment, and described the transmission of sound from the microphone to the receiver. Inspection of the equipment followed. Dec. 9. Att. 109.

Madison

Characteristics of Program Supply Circuits for Radio Broadcasting, by N. H. Blume, Wisconsin Tel. Co. Inspection trip through the telephone company's exchange. Dec. 14. Att. 47.

Memphis

Annual dinner meeting. Election of officers: G. O. Macfarlane, chmn.; F. L. Christenbury, secy.; O. F. Long, treas.; S. C. Commander, M. J. Mallery, and W. A. Gentry, directors. Dec. 13. Att. 52.

Mexico

Discussion. Dinner. Nov. 30. Att. 34.

New York

Cosmic Rays, by Dr. K. K. Darrow, Bell Tel. Labs., Inc. Communication meeting. Dec. 13. Att. 1100.

Niagara Frontier

Economics of the Power Industry, by Col. Wm. Kelly. Buffalo, Niagara & Eastern Pwr. Corp. Illus. Dec. 16. Att. 110.

Philadelphia

Applications of Electricity in the Field of Medicine, by J. L. Weatherwax, Philadelphia General Hospital, and A. Margolies, S. E. Pond, and S. R. Warren, Jr., of the Univ. of Pa. Dec. 12. Att. 165.

Pittsburgh

Industrial Heating, by A. N. Otis, Genl. Elec. Co. Illus Dec. 13. Att. 87.

Pittsfield

High Voltage Stars, by Dr. C. H. Payne, Harvard Univ. Observatory. Dinner. Dec. 20. Att. 230.
Shippee-Johnson Expedition to the Peruvian Andes, by Robert Shippee. Jan. 3. Att. 1200.

Portland

Laying of 115 Kv Cable—Columbia River Crossing, by E. F. Pearson and S. B. Clark, both of the Northwestern Elec. Co.; Observations of Failures in Cable Splices and Terminals, by J. S. Volpe, Portland Genl. Elec. Co. Dec. 13. Att. 45.

Providence

Wiring Equipment for Hazardous and Explosive Locations, by W. M. Runyon, Crouse-Hinds Co. Illus. Dinner. Dec. 12. Att. 33.

Rochester

Centralized Traffic Control Systems, by C. S. Bushnell, Gen. Railway Signal Co. Illus. Joint meeting with I.R.E. and Rochester Engg. Soc. Dec. 15. Att. 40.

St. Louis

Light and Illumination, by B. F. Thomas, Jr., cons. engr. Dec. 21. Att. 26.

Sharon

The Art of Electrical Distribution, by C. T. Sinclair, Byllesby Engg. & Mgmt. Corp. Film—"Electricity Goes to Sea." Dec. 13. Att. 116.

Spokane

Dr. R. A. Millikan and Dr. Neher described the instruments used in their experiments in measuring the cosmic ray. Sept. 23. Att. 15.
Prof. R. H. Hull, Univ. of Idaho, discussed Institute activities. Oct. 28. Att. 10.

Springfield

Air Conditioning, by R. S. Thurston, Genl. Elec. Co. Illus. Dec. 12. Att. 108.

Toledo

Simple Principles of D-C Machinery, by N. B. Thayer; L. A. S. Wood, Westinghouse Elec. & Mfg. Co., explained the necessity of adequate street and highway illumination. Film—"The Installation of a Modern Street Lighting System." Dec. 16. Att. 75.
Executive committee meeting. Jan. 4. Att. 8.

Toronto

Starting Synchronous Motors, by J. Leech-Porter, Canadian Westinghouse Co. Dec. 16. Att. 67.

Washington

Patents As Related to the Electrical Industry, by T. E. Robertson, U.S. Patent Office. Dinner. Dec. 13. Att. 75.

Worcester

Inspection trip to the American Steel & Wire

Company's electrified rod mill. Nov. 16. Att. 15.

CRANKING UP A POWER STATION IN SIAM, by L. S. Leavitt, Worcester Elec. Lt. Co. Dec. 15. Att. 30.

Past Branch Meetings

University of Akron

RELAYS, by F. J. Marcinkoski, student. Dec. 8. Att. 16.

University of Arizona

Discussion of practical problems in electrical engineering. Nov. 18. Att. 6.

Business Meeting. Dec. 2. Att. 5.

University of Arkansas

BANKERS AND DAMS, by Prof. A. W. Jamison; HISTORY, MANUFACTURE, AND OPERATION OF NEON LIGHTS IN ADVERTISING WORK, by H. H. Lewis, student; WELDING IN HYDROGEN ATMOSPHERE, by G. G. Sherland, student. Dec. 8. Att. 27.

Armour Institute of Technology

AUTOMATIC DIAL TELEPHONES AND THEIR CIRCUITS, by Mr. Levy and Mr. Probst, both of the Automatic Elec. Co. Dec. 2. Att. 33.

LABORATORY METHODS IN THE CONSTRUCTION OF RADIO SETS, by Mr. Dunn. Dec. 16. Att. 25.

Polytechnic Institute of Brooklyn

THE USES OF THE CATHODE RAY OSCILLOGRAPH, by G. Danos, student. Dec. 8. Att. 43.

California Institute of Technology

THE ECONOMIC DEVELOPMENT IN RUSSIA, by A. Gould, Genl. Elec. Co. Illus. Dec. 8. Att. 60.

Carnegie Institute of Technology

TEST OF ALUMINUM STRUCTURES, by R. T. Templin, Aluminum Co. of America; OVERHEAD IN A CORPORATION, by P. T. McClure, Genl. Elec. Co. Joint meeting with Theta Tau. Dec. 14. Att. 21.

Clemson Agricultural College

A BRIDGE METHOD OF TESTING WELDS, by C. M. Evans; ORGANIZATION OF A.I.E.E., by D. E. Penney, CURRENT EVENTS, by J. T. Steppe; REPORT ON A.I.E.E. MEETING AT KNOXVILLE, by C. P. Walker, all students. Dec. 6. Att. 40.

Colorado Agricultural College

THE PHOTOELECTRIC RELAY, by Prof. H. G. Jordan. Demonstrations. Jan. 2. Att. 17.

University of Colorado

THE N. Y. EDISON CO. WITH SPECIAL REFERENCE TO THE EAST RIVER PLANT, by S. W. Hannah, student. Illus. Nov. 30. Att. 24.

Cornell University

SOME PROBLEMS OF HIGH TENSION POWER TRANSMISSION LINE ENGINEERING, by J. Allen Johnson, vice-pres., A.I.E.E., Buffalo, Niagara & Eastern Pwr. Corp. Illus. Dec. 9. Att. 80.

University of Denver

Discussion. Nov. 10. Att. 16.

Inspection trip through the Great Western Sugar Co. Nov. 18. Att. 15.

Demonstration of a short wave radio set. Nov. 28. Att. 116.

Inspection trip through the government building in Denver. Dec. 13. Att. 14.

University of Detroit

DESIGN OF RADIO FOR AIR CRAFT, by R. Collignon, Trans-American Air Lines. Films—"The Radio Beacon" and "Guiding Airplanes by Radio." Dec. 14. Att. 44.

Duke University

OFFENSIVE FOOTBALL, by A. H. Werner, student. T. J. Garrett, chmn., outlined the events at the Conference on Student Activities held at the Univ. of Tenn. Dec. 14. Att. 21.

University of Idaho

AERIAL PHOTOGRAPHY, by B. Alworth, student. Demonstration of a photoelectric cell, by O. Carpenter and B. Clagett, students. Dec. 1. Att. 40.

EXPERIENCES OF A GRADUATE IN ENTERING EMPLOYMENT OF WESTINGHOUSE, by J. Rogers, Westinghouse Elec. & Mfg. Co. Dinner. Dec. 8. Att. 37.

Iowa State College

PHOTOELECTRIC AND GLOW DISCHARGE DEVICES AND THEIR APPLICATION TO INDUSTRY, by R. H. Maxwell, Westinghouse Elec. & Mfg. Co. Nov. 15. Att. 100.

Election of officers: R. S. McCready, chmn.; J. W. Foster, vice-chmn.; J. E. Bogard, secy.; E. S. Griffith, treas. Dec. 8. Att. 24.

University of Iowa

TRANSMISSION ENGINEERING, by Mr. Sampson, Northwestern Bell Tel. Co. Dec. 7. Att. 33.

University of Kansas

BACTERIA IN EVERYDAY LIFE, by N. P. Sherwood. Dec. 14. Att. 38.

University of Kentucky

APPEARANCE AND COURTESY, by Major J. B. Brewer; PUSH-PULL CONDENSER MICROPHONE, by J. E. Barlow and J. C. Starks, students.

Lafayette College

THE CATHODE RAY OSCILLOGRAPH, by V. F. Rigling; ELECTRIC SHOCK, by Dr. W. B. Kouwenhoven, vice-pres., A.I.E.E., Johns Hopkins Univ. Joint meeting with Lehigh Univ. Branch. Dec. 2. Att. 75.

Business meeting. Dec. 13. Att. 20.

ARTIFICIAL LIGHT VERSUS SUNLIGHT, by M. Ziev, student; ESTIMATION OF UNDERGROUND CONDUITS, by D. MacDougall, student. Dec. 16. Att. 15.

Lehigh University

Joint meeting with Lafayette Col. Branch. (See report under Lafayette College.)

University of Louisville

Discussion. Dec. 15. Att. 15.

University of Michigan

ASPECTS OF THE JOB SITUATION, by A. M. Dudley, Westinghouse Elec. & Mfg. Co. Dec. 12. Att. 52.

Milwaukee School of Engineering

ENGINEERING IN NAVIGATION, by Prof. J. D. Ball. Dec. 15. Att. 81.

Inspection trip to the S. S. Philip D. Block. Dec. 17. Att. 40.

University of Minnesota

ROMANCE OF GLASS MAKING, by A. S. Tyler, Chicago Glass Co. Dec. 8. Att. 300.

NEON SIGNS, by L. Markus, student; THE MAKING OF SMALL ARMS AMMUNITION, by H. Sanderson, student. Dec. 9. Att. 25.

University of Missouri

PREPARING THE BAGNALL DAM RESERVOIR FOR IMPOUNDING, by D. A. Harvey, student. Jan. 4. Att. 22.

Montana State College

THE PHOTOELECTRIC CELL, by C. Schmitz; SEALED CONSTRUCTION FOR LIGHTNING ARRESTERS, by G. W. Roberts; RADIATION COOLED POWER TUBES FOR RADIO TRANSMISSION, by B. Roberts; INDICATORS AS A MEANS OF IMPROVING AIRCRAFT ENGINE PERFORMANCE, by R. L. Spaulding; THE TRANSMISSION ENGINEER'S JOB, by G. Misevic, all students. Dec. 1. Att. 81.

SOME PSYCHOLOGICAL EFFECTS OF ELECTRICITY, by Prof. C. F. Bowman; RESEARCH INJURIES FROM ELECTRIC SHOCK, by D. Towne, student; ARTIFICIAL SUNSHINE, by A. White, student. Dec. 8. Att. 82.

University of Nebraska

THE TELETYPEWRITER, by Prof. F. W. Norris, counselor. Dec. 7. Att. 25.

Newark College of Engineering

TELEPHOTOGRAPHY, by W. C. Bettinson, N. J. Bell Tel. Co. Dec. 19. Att. 27.

University of New Hampshire

Discussion. Dec. 3. Att. 29.

Films—"How the General Electric Icing Unit Works" and "Ties of Steel." Dec. 10. Att. 27.

Film—"On the Pathways of Progress." Jan. 7. Att. 31.

College of the City of New York

SYSTEM STABILITY, by Robert Treat, Genl. Elec. Co. Dec. 8. Att. 40.

AIR CONDITIONING, by W. F. Carrier, Carrier Engg. Co. Joint meeting with A.S.M.E. and A.S.C.E. Branches. Dec. 15. Att. 100.

Smoker. Dec. 16. Att. 122.

New York University

THE ELECTRON, by John Lieb; OVERSEAS TELEPHONE SERVICE, by Harry Wong; PEAKED WAVE TRANSFORMERS, by Wm. Knauert, all students. Dec. 16. Att. 21.

University of North Carolina

THE FUNDAMENTALS OF RATE MAKING, by Prof. W. J. Miller. Dec. 8. Att. 20.

University of North Dakota

ELECTRIC POWER PLANTS, by Mr. Linn, city engr. Dec. 14. Att. 18.

Oregon State College

LEASED WIRE SERVICE AND FACILITIES, by A. K. Morehouse, Bell Tel. Co. Illus. Dec. 1. Att. 42.

Pennsylvania State College

TALKING MOVIES, by Prof. E. B. Stavely. Nov. 9. Att. 52.

Pratt Inst.

STUDENT MEMBERSHIP IN THE A.I.E.E., by J. G. Allison, chmn. Sept. 28. Att. 26.

SHORT WAVE TEST LABORATORY, by H. Harrison, student. Demonstrated. Oct. 12. Att. 30.

MARINE RADIO DIRECTION FINDERS, by A. Davis, student. Nov. 2. Att. 20.

THE EIGHTH AVENUE SUBWAY, by R. Farrell, student. Illus. Nov. 22. Att. 33.

Film—"Power." Dec. 12. Att. 44.

Purdue University

OSCILLOGRAPH—A MODERN TABLOID REPORTER, by Prof. G. V. Mueller. Demonstrated. Dec. 9. Att. 100.

Rensselaer Polytechnic Institute

SOME RECENT HYDROELECTRIC DEVELOPMENTS, by A. C. Clagher, Elec. Bond & Share Co. Dec. 13. Att. 150.

Rhode Island State College

THE PARALLEL TYPE INVERTER, by Prof. F. N. Thompkins, Brown Univ. Dec. 15. Att. 20.

Rose Polytechnic Institute

ELECTRICAL INDUSTRY, by W. L. Brown, student; THE PUBLIC UTILITY DOLLAR, by H. M. Phillips, student. Dec. 12. Att. 29.

FUSEOLOGY, by E. J. Withers, student; NOFUSE CIRCUIT BREAKER, by E. H. Schroeder, student. Jan. 9. Att. 31.

Rutgers University

ELECTRIC SHIP PROPULSION, by L. V. Banta, student. Dec. 13. Att. 10.

University of South Carolina

HIGH TEMPERATURE INSULATION, by Daniel Frick, student. Joint meeting with A.S.C.E. Branch. Jan. 10. Att. 77.

South Dakota State School of Mines

Discussion. Dec. 14. Att. 35.

Syracuse University

110 KV TRANSMISSION LINES, THEIR MAINTENANCE AND TIES WITH OTHER SYSTEMS, by L. J. Audlin, Syracuse Ltg. Co. Dec. 13. Att. 23.

TELEVISION SCANNING, by A. Paucek, student; POWER DISTRIBUTION, MUNICIPAL VS PRIVATELY OWNED COMPANIES, by C. Middleton, student. Dec. 20. Att. 23.

Texas A. & M. College

Film—"Dynamic America." Dec. 16. Att. 100.

Texas Technological College

TECHNOCRACY, by A. Wiggins, student; THE USE OF THE CHART IN ADDING AND SUBTRACTING POLAR VECTORS, by T. Rowley, student. Nov. 13. Att. 17.

University of Utah

Films—"Making of Incandescent Lamps" and "Electric Ship." Nov. 30. Att. 44.

MAKING OF BOULDER DAM, by R. J. Brown, Westinghouse Elec. & Mfg. Co. Dec. 14. Att. 68.

Virginia Polytechnic Institute

THE PUSH-PULL CONDENSER MICROPHONE, by E. W. Seay; THE ELECTRICAL SHOT-GUN PRESSURE GAGE, by W. L. Outten; CONTROL OF LIGHTS BY THE PHOTOELECTRIC CELL, by N. R. Waldrop; OUR LATEST ELECTRICAL EXPERIMENTS, by N. C. Smoot; MICROPHONES, by W. C. Cottrell; REDUCING NOISES IN RADIO, by E. M. Richardson; RADIO NETWORK BROADCASTING SYSTEMS, by D. L. Webster, all students. Dec. 13. Att. 41.

University of Washington

CONQUEST OF THE CASCADES, by Glenn Walker, Great Northern Ry. Dec. 8. Att. 30.

University of Wisconsin

Discussion of the subject SHALL WE HAVE PUBLIC OWNERSHIP OF PUBLIC UTILITIES? Nov. 30. Att. 22.

Employment Notes

Of the Engineering Societies Employment Service

Men Available

Construction

PRACTICAL ELEC CONSTR. CHIEF, 32, single, desires work along elec. construction lines, willing to travel anywhere; 14 yr practical experience in the construction, maintenance, and operation of industrial plants and mines. Last 4 yr in Latin America. Speaks Spanish and German fairly well. Available immediately. Location, immaterial. C-2101.

ELEC CONSTR. FOREMAN, 34, married, with 3 yr E.E. course and 10 yr practical experience. Five yr in substations, indoor, outdoor, and automatic; 1 in plant construction; 4 in transmission lines and distribution systems; $1^1/_2$ yr in South America as supt. Speaks Spanish and German. C-4164.

GRAD. E.E., 30, 5 yr supervisory construction, design, estimating, and field engg experience on super-power plants and substations; 4 yr industrial power plant operation. Elec. construction and maintenance experience, ry. electrification construction experience. C-4428.

Design and Development

GRAD. E.E. of Purdue, 19 yr experience covering design, and construction of pwr. plants, indoor and outdoor substations, transmission lines, elec construction on paper and steel mills, hydroelectric plants. Also valuation, appraisal, inventory, rates, financial statistics, and annual reports; 2 yr engg sales. G.E. test. Available now. Location, immaterial. C-8256.

PRACTICAL ELEC DESIGNER with univ. training and 17 yr experience in elec field covering design and supervision of layout for elec lt. and pwr. installations in industrial, school, and office bldgs., also design of special equip. for ltg., fire signal, and interior telephone systems. N. Y. City location preferred. B-1483.

ELEC-MECH. ENGR, 32, col. grad.; 10 yr diversified experience including $1^1/_2$ yr pwr. plant operation and maintenance; $2^1/_2$ yr design, construction, and system development for large utility; $3^1/_2$ yr plant engg with large industrial concern. C-5727.

B.E.E. DEG., 28, married. Six yr electrician including maintenance, pwr. house construction, substation operating and maintenance. Also elec repair; 1 yr in E.E. dept. doing design and layout work including substation design, ltg. and pwr. layout, ry. electrification and application of industrial control. Desires E.E. or drafting position. D-1777.

MECH. AND ELEC ENGR, inventive, analytical, mature; 30 yr designing engr. Genl. Elec., Crocker Wheeler, and Westinghouse. Wide experience in motor control systems and apparatus. Inventions extensively used. Desires development work in same or related fields or as consultant. Salary to suit location and duties. A-2110.

ELEC ENGR AND DESIGNER, transformers and resistance welding machinery; 30, married, graduate Canadian univ., Westinghouse test floor and student course. Westinghouse design school. Three yr designing pwr. and distribution transformers, current limiting reactors; 1 yr design and development resistance welding machy. Some control and maintenance experience. Available immediately. C-9734.

E.E., 34, 10 yr experience covering design, cost estimating and equipment specifications of pwr. plants, industrial bldgs., copper and oil refineries, substations and transmission lines. Also $^1/_2$ yr as asst. research engr with cable co. and 1 yr as tester with elevator co. English and German languages. C-5473.

DESIGN ENGR, B.S. in E.E. grad., desires position in engg or teaching. Experience: 1 yr d-c test work, 4 yr development and application of hardware for outside plant telephone use, also practical experience in plumbing, steam fitting, and engine operation. Salary and location open. D-1305.

Executives

ENGR. Qualified to direct all activities of utility operating or design divisions. Familiar with the necessary organization and equipment for economical operation, maintenance, development, and construction; 12 yr utility experience. Location, immaterial. Available at once. Married. C-4734.

SUPT., ELEC-MECH. ENGR; 25 yr experience. Married, needs position. Supt. mfg. plant, design, construction, operation, maintenance, mfg., valuation; 10 yr hydroelectric experience; 14 yr mfg., $3^1/_2$ yr supt. radio mfg. Speaks French. Salary open. Location open. Prefer Chicago or Calif. Best references. Available now. D-1780.

E.E. GRAD., New York Univ. 1930. Administive, development, inspection, design, patent and operating experience. Formerly examining officer and inspector in charge of branch office of Federal Radio Commission. Interested in a position that could beneficially utilize aforementioned service. Will consider any location. Immediately available. D-1804.

GRAD. ELEC, HYDRO-ELEC ENGR, 32, married, 2 yr experience marine elec installation; 8 yr design, construction of steam, hydro pwr. plants, outdoor, indoor substations, transmission, distribution lines, wiring diag., indus. plants, office buildings, estimating, preparation of specifications. Desires position, utility, consulting engg firm, industrial concern. Consider any location. Available immediately. D-212.

E.E., 39, married, 20 yr experience in design, construction, maintenance and operation of industrial plants and mines. Exec. and foreign experience. References. Available immediately. Location, immaterial. D-1833.

ENGR, M.E., experienced in research, design and estimating. Mchy., factory, mill, RR, mining, plant and bldg. layout; 15 yr with present employer as technical writer of sales, purchase, performance, test specifications, and other publications. Specially qualified for inspection of materials, machy., processes and structures. D-1813.

E.E. GRAD., 1930, married, 26, valuable experience with pwr. co. testing and regulating automatic apparatus, high voltage testing and research work. Desires position in pwr. transmission field or with mfr. of automatic apparatus. Excellent references. Available at once. D-1838.

B.S. in E.E. 1932, Univ. of Colo., 22, married, desires position with a pwr. co., mfg. establishment, constr. or cons. firm. Will go anywhere and work hard for a living wage. Available at once. References. D-1835.

E.E. GRAD., Iowa State Col., '32, 22, single, earned way through col. Excellent scholastic record. Member, Eta Kappa Nu and Phi Kappa Phi. Ambitious, honest, reliable. Communication (telephone, radio) major work in col. Desires E.E. work that will lead to responsible position. Good references at col. Location, immaterial. D-1834.

E.E. GRAD. 1928, 25, 3 yr G.E. test, development and constr. work; 2 summer vacations Stone & Webster constr. on hydroelectric plant. G.E. courses and considerable graduate study. Available now. Location, immaterial. C-9683.

E.E. GRAD., 1932, Rensselaer Polytech. Inst., 22, single. Factory and drafting experience. Desires work in any elec field. Location and salary, immaterial. Available immediately. D-1827.

M.Sc. in E.E. '32, Ohio St. Univ. Grad. work, communication engg. B.S. in E.E. '30, Iowa St. Col.; 1 yr RCA Victor Co., Inc., student engr course. Designed and built frequency checking equipment for broadcasting station. Have pwr. distribution experience. Have pub. tech. paper, IRE. Wants responsible work. Location, immaterial. Available immediately. D-1798.

PURDUE GRAD., 1929, B.S. of E.E., 26, single. Six mos with radio mfr., 1 yr extensive utility training course, 6 mos in engg office. References. Desires employment with utility or mfr. D-1801.

I.E.E. GRAD., Pratt Inst., 1932, 20, single. Specialized illumination. Completed Westinghouse illum. course. Capable and not afraid of hard work. Excellent references. Desires any kind of work in elec field. Location, immaterial. Available immediately. D-1594.

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GRAD. ENGR, 31, specializing in overhead and underground transmission and distribution problems. Ten yr experience, mgmt. utility, includes: design and construction low voltage a-c networks, urban, rural, and industrial electrification, rehabilitation of generating plants and substations, distribution standardization including executive control of operation, reconstruction and reorganization, budgets, reports, analyses, valuation. B-6934.

DIRECTOR OF RESEARCH IN INDUSTRIAL OR IN EDUCATIONAL INSTITUTION, mature man, extensive experience, engg teacher, cons. engr, executive officer with well-known institutions. Intimately acquainted, utility problems; inventory, P.S.C. procedure, sales development, and publicity work. Interested, position which might become permanent rather than one to fill a temporary vacancy. C-6733.

Junior Engineers

E.E. GRAD., M.I.T., S.M. 1932. Tau Beta Pi; fellowship; grad., Episcopal H.S., Va., 6 mos cooperative student, G.E.; 6 mos development work with well-known engr; typewrites. Employed, not elec field. Desires position, utility or mfr. Nominal salary. Eastern U.S. preferred. References. D-1831.

E.E. GRAD., 24, Lafayette Col., '31, married. Ten mos experience with large belting co., 1 yr sales experience. Desires position with large mfg. or engg corp. Salary and location secondary, but prefer eastern U.S. Available immediately. C-9422.

E.E. GRAD., 1932, Miss. State Col., 22, single. Desires engg work, but will consider anything. Location, immaterial. Available immediately. D-1570.

B.S. in E.E., 1932, Ohio Northern Univ., 23, single. Good character and plenty of references. Elec wiring experience and training in elec design. Desires any position that will pay living wage. Location, immaterial. D-1814.

E.E. GRAD., Univ. of Wis., 1932, 23, single. Some experience in line and service work. Member of Eta Kappa Nu. Desires position affording experience and possible advancement. Salary and location secondary. Available immediately. D-1828.

E.E. GRAD., B.S. Carnegie Inst. of Tech. 1932, 22, married, varied experience in elec maintenance work. Switchboard wireman. Drafting room experience. Member of Tau Beta Pi and Eta Kappa

Nu. Experience in elec work desired. Location and salary, immaterial. Available at once. D-1826.

B.S. and E.E., Mich. State Col., 31, G.E. test, 4 yr practical experience with (manual, supervisory controlled, and automatic) pwr. substations, automatic ry. substations (rotary converter and rectifier) and (frame mounted, cell mounted, and metal-clad) equipment. Willing to do engg, operating, or teaching. D-1597.

COMMUNICATIONS ENGR, Grad. M.I.T., S.B. '31, Sm. '32, 24, manuf. practice, Western Elec, field practice, Western Elec and N. Y. Telephone Co., research practice, Bell Tel. Labs., Inc. Coauthor, "The History of Frequency Channel Requirements in Electrical Communication." Available, permanent connection or consultant, any type signal or communication work, including applications, electronics, acoustics. D-1829.

GRAD. E.E. 1929, G.E. test experience, including work in radio and vacuum tube engg depts. and with all types of elec machy. Utility elec rate analysis experience covering pwr. companies in all states. Received M.S. in June 1932. Desires an engineering opportunity. D-1036.

Maintenance and Operation

GRADUATE E.E., '29, Bklyn. Poly., 16 mos G.E. Test, 20 mos foreign contract in S.A., working knowledge of Spanish, handle maintenance work on automatic switchboards, Ward-Leonard control, elec locos., etc. Available immediately and will travel anywhere. Excellent references. D-1793.

E.E. GRAD., A.I.T., married. Specialized experience in automotive armature rewinding, core conversions, shafts; also fan, drill, and fractional hp armature rewinding. Field coil winding and old generator salvage. Location anywhere; available at once. Excellent references. C-8668.

E.E., univ. grad., single, 30, 9 yr experience in maintenance work on both d-c and a-c machy. Capable of taking charge of maintenance dept. in factory or mine. D-1816.

Sales

B.S. in E.E. 1928, 26, single, desires connection as a sales engr with co. handling pwr. plant or elec machy. Experience includes 1 yr student engr and 3 yr in telephone sales dept., Western Elec. Co. Location in the South preferred. D-1806.

INDUSTRIAL CONTROL ENGR, covering western New York territory as sales representative for mfr. of elec control devices desires additional accounts to complete line. Extensive experience in industrial engg field assures correct application of equipment. Particular attention to items with repeat demand. Headquarters, Rochester. D-1273.

SALES CONTACT E.E. REPRESENTATIVE, experienced in introducing new lines, lecturing, catalog work, etc. Desires position with high grade co. having industrial or utility line of equipment. B-4067.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the address as it now appears on the Institute records. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Anderson, F. C., 741 Oak Ave., Westfield, N. J.
Bell, E. DeWitt, 335 River Road, Bogota, N. J.
Carlsen, O. Grag, 635—72nd St., Bklyn., N. Y.
Heiser, Edwin S., 413 Federal Bldg., St. Paul, Minn.
Johann, Chas. S., 358 Weaver St., Larchmont, N. Y.
Johns, Francis J., Westinghouse Club, Wilkinsburg, Pa.
Katz, Henry, 2714 Wallace Ave., New York, N. Y.
Lutz, Robert S., 24 Brooke Ave., Rochelle Park, N. J.
Peterson, Alex., Central West Pub. Serv. Co., Omaha, Neb.
Pool, Russell P., 209 S. Kenilworth, Oak Park, Ill.
Smith, Frederic V. M., Texlite Elec. Sign Co., 4112 Commerce St., Dallas, Texas.
Thornton, George C., P. O. Box 904, Birmingham, Ala.
Weber, Joe, 705—18th St., N.W., Washington, D. C.
Wiles, Warner M., c/o Intl. Rwy. Co., 855 Main St., Buffalo, N. Y.

Membership

Recommended for Transfer

The board of examiners, at its meeting of January 18, 1933, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Dahl, Otto G. C., prof. of elec. pwr. trans., Mass. Inst. of Tech., Cambridge.
Stoekle, Erwin R., v.-p. in charge of dvpt., Globe-Union Mfg. Co., Milwaukee, Wis.

To Grade of Member

Codding, Laurence W., engr., trans., Pub. Serv. Elec. & Gas Co., Newark, N. J.
Fitzgerald, Joseph W., engr., Ohio Bell Tel. Co., Cleveland.
Huffman, Harold F., assoc. prof. of E.E., Southern Methodist Univ., Dallas, Texas.
Kolodziej, Paul J., foreman, distribution planning div., Lynn Gas & Elec. Co., Mass.
Landis, George H., supt. of trans., Central Hudson Gas & Elec. Co., Poughkeepsie, N. Y.
Marshall, Samuel W., Jr., member of firm, Marshall and Sewell, Dallas, Texas.
McDaniel, Alexander H., E.E., pres., Alexander H. McDaniel, Inc., Wilmington, Del.
Reid, Paul H., Serv. engr., The Roessler & Hasslacher Chem. Co., Niagara Falls, N. Y.
Wilson, James McCown, division mgr., Va. Pub. Serv. Co., Clifton Forge.

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the acting national secretary before Feb. 28, 1933.

Abel, E. LeR., Lebanon, Conn.
Allen, E. J., 123 a Charles St., Jersey City, N. J.
Allen, S. L., 177 Main St., Danielson, Conn.
Bachman, C. H., Iowa St. Col., Ames, Iowa.
Bailey, W. E., 2733 Bardstown Rd., Louisville, Ky.
Baker, G. W., Columbia Univ., N. Y. City.
Baker, P. E., 25 N. Dearborn St., Indianapolis, Ind.
Bangerter, H. G., Sherwood Radio Co., Albuquerque, N. M.
Banks, C. W., Wire & Cable Co., Trenton, N. J.
Barber, C. D., Ford Motor Co., Kansas City, Mo.
Barker, H., Fabrica "San Jose de la Montana," Queretaro, Qro., Mexico.
Baron, A. R., 212 Sidney St., St. Louis, Mo.
Bayha, L. H., 1715 S. 7th St., Alhambra, Calif.
Berger, L. C., Ohio State University, Columbus, O.
Bernhardt, H. A., Guntown, Miss.
Birchard, W. E., Iowa St. Col., Ames.
Boltz, J. H., Gibbs & Hill, N. Y. City.
Bong, T. C., Univ. of Wash., Seattle.
Bradford, J. K., 935 Somerset St., W. Ottawa, Can.
Breault, L. C., 450 S. Main St., Woonsocket, R. I.
Brown, A. W., R. F. D. No. 2, Tampico, Ill.
Budelman, F. T., Ridge Rd., Great Notch, N. J.
Bullwinkle, R., Interborough Rapid Transit Co., N. Y. City.
Cafarelli, S., 756 Union Ave., N. Y. City.
Carleton, D. B., Am. Steel & Wire Co., Trenton, N. J.
Chewning, A. E., The Detroit Edison Co., Mich.
Corcoran, G. F., (Member) State Univ. of Iowa, Iowa City.
Crisman, F. K., 526 W. Front St., Berwick, Pa.
Crockett, J. G., 580 E. Geneva Ave., Phila., Pa.
Dearing, R. W., The Detroit Edison Co., Mich.
DeBever, O. J., Pub. Serv. Co. of No. Ill., Evanston, Ill.
Depew, G. M., Summer Shade, Ky.
Dickey, W., 8910 Cicero Ave., Niles Center, Ill.
Dison, E. M., Canyon, Texas.
Dougherty, F. E., Genl. Elec. Co., Schenectady, N. Y.
Dow, D. C., 154 Parkway South, Mt. Vernon, N. Y.
Drescher, J. F., U.S. Reclamation Service, Boulder City, Nev.
Dunn, C. J., 1065 Anderson Ave., N. Y. City.
Edick, R. S., 354 E. Main St., Ilion, N. Y.
Eggers, E. B., Northern States Pwr. Co., Minneapolis, Minn.
Elliott, C. H., Hobart Estate Co., Hobart Mills, Calif.
Estel, G. A., Jr., Iowa Engg. Co., Inc., Des Moines.
Etchells, E. B., Schwarze Elec. Co., Adrian, Mich.
Everett, L., Jr., Box 2293, Stanford Univ., Calif.
Fisher, E. W., Kansas Pwr. & Lt. Co., Topeka.
Fitz, O. R., 42-10 215th St., Bayside, L. I.
Flagg, H. J., Genl. Cable Corp., Rome, N. Y.
Ford, L. S., Jr., Bd. of Water & Elec. Lt. Comm., Lansing, Mich.
Ford, W. A., Jr., Austin Powder Co., McArthur, Ohio.
Francis, J. S., Mich. Col. of Mining & Technology, Houghton.
Fredenhall, G. L., Univ. of Wis., Madison.
Godfrey, E. S., Jr., 113 Argyle Pl., Arlington, N. J.
Goodrich, R. D., Jr., Univ. of Wyoming, Laramie.
Grimes, C. G., U.S.S. New Mexico, c/o Postmaster, Phila., Pa.
Hagen, R. M., United Elec. Lt. & Pwr. Co., N. Y. City.
Hall, L. D., (Member) Box 68, Big Flats, N. Y.
Hamilton, R. W., 292 Lincoln St., Allston, Mass.
Hand, T. M., Alabama Pwr. Co., Bay Minette.
Hardy, J. E., Medical Arts Bldg., Grand Rapids, Mich.
Harshbarger, L. A., Shelby County Pub. Schools, Sidney, Ohio.
Heath, M. W., 20 W. 44th St., N. Y. City.
Hendrix, H. B., R. F. D. 3, Cullman, Ala.
Higgins, L. W., 18035 Ilene Ave., Detroit, Mich.
Hild, D. F., Central West Pub. Serv., Cando, N. D.
Hodges, A. R., 51 Sherman Place, Ridgewood, N. J.
Hoerter, J. A., 210 Van Nostrand Ave., Jersey City, N. J.
Holland, M. D., Station WEAF, N. B. C., Inc., N. Y. City.
Howes, H. F., Howe St., Ashland, Mass.
Hubbell, G. H., 1144 W. Broad St., Stratford, Conn.
Huggler, C. M., 516 So. Arkansas Ave., Russellville, Ark.
Hull, F. M., Detroit Edison Co., Mich.
Hutchinson, J. A., 2810 Washington St., San Francisco, Calif.
Ince, F. E., Yale Radio & Elec., Maplewood, Mo.
Jamart, G. E., 416 Alvarado St., San Francisco, Calif.
Johnson, P. J., Genl. Elec. Co., West Lynn, Mass.
Johnston, E. L., Dept. of Grounds & Bldgs., State Col., Pa.
Kalen, L., Central States Elec. Co., Cedar Rapids, Ia.
Kaufmann, H. W., R. C. A. Radiotron Co., Harrison, N. J.
Kneisley, R. F., Strong Elec. Corp., Toledo, Ohio.
Kolb, L. W., Park Ridge Cleaners, Inc., Park Ridge, Ill.
Korrell, P. H., 2802 St. Charles Road., Bellwood, Ill.
Kouthik, E. A., 4906 Federal Blvd., Denver, Colo.
Kubin, K. F., R. No. 1, Willis, Mich.
Kummer, E. F., U. S. Coast & Geodetic Survey, N. Arlington, N. J.
Lambert, J. L., 408 E. Patterson Ave., Connellsville, Pa.
Lehman, H. W., 270 W. Lane Ave., Columbus, Ohio.
LeVan, H. C., 46 South Main St., Watsontown, Pa.
Levy, N., Haaren High School, N. Y. City.
Lewis, G. C., United Elec. Lt. & Pwr. Co., N. Y. City.
Lindfors, O., Danville Iron & Steel Co., Danville, Pa.
Lorenz, H. F., Washington Ave., Meriden, Conn.
Losoncy, W. A., Ford Motor Co., Dearborn, Mich.
Lower, R., County Highway Dept., Weld County, Colo.
Lundberg, F. C., Univ. of Utah, Salt Lake City.
Mackerman, J. L., 98 E. Wyoming Ave., Melrose, Mass.
Madsen, R. V., Southern Pacific Golden Gate Ferries, San Francisco, Calif.
May, H., Landers, Frary & Clark, New Britain, Conn.
Mayleas, Ludwig B., N. Y. Tel. Co., N. Y. City.
Maynard, J. S., Howard & Center Sts., Baltimore, Md.
Meko, E. P., Genl. Elec. Co., Cleveland, Ohio.
Merriman, F. J., Case Sch. of App. Sci., Cleveland, O.
Meyer, R. C., Mass. Inst. of Tech., Cambridge.
Millheisler, C. A., (Member) Hearst Publications, Chicago, Ill.
Milstein, L., 576 Eastern Parkway, Bklyn., N. Y.
Minter, S. R., Virginia Poly. Inst., Blacksburg.
Miyota, N. S., 916 1/2 Howell St., Seattle, Wash.
Monteith, V. St. C., Jr., West Virginia Univ., Morgantown.
Moore, D. T., 10609 Orville Ave., Cleveland, O.
Naughton, D. J., 25-81 31st St., Long Island City, N. Y.
Needham, D. P., Iowa State College, Ames.
Nefzger, H., 80 Bidwell Ave., Jersey City, N. J.
Nelson, R. E., 55 W. 75th St., N. Y. City.
Northrup, G. E., (Member) The Scranton Elec. Co., Scranton, Pa.

Onori, G. S., Pennsylvania State Highway Dept., Greensburg.
Osborne, A. I., 210 Lavalette Ave., Norfolk, Va.
Osborne, E. G., Jr., 104 Garden Rd., Larchmont, N. Y.
Owens, J. C., South River, Md.
Painter, L. E., Anaconda Copper Mining Co., Washoe, Mont.
Pajerski, H. T., Ray Brook, N. Y.
Palmer, R. D., N. Y. Life Ins. Co., Denver, Colo.
Pantz, T. L., Marchant Calculating Machine Co., N. Y. City.
Peterson, E. F., Sterling College, Sterling, Kans.
Plummer, C. E., Turlock Irrigation Dist., Turlock, Calif.
Pries, L. T., Colonial Radio Corp., Buffalo, N. Y.
Randall, H. D., Jr., Picker X-Ray Corp., N. Y. City.
Raynor, W. McL., Phila. Elec. Co., Pa.
Reader, H. E., 207 E. 8th St., Pueblo, Colo.
Robeck, C. A., Republic Theatre, Annapolis, Md.
Robb, C. D., Detroit Edison Co., Mich.
Roblee, J. E., Yale Univ., New Haven, Conn.
Roll, J. R., 962 S. 9th St., San Jose, Calif.
Rupf, J. A., 10 Hillhouse Ave., New Haven, Conn.
Rust, G. D., Pub. Serv. of N. J., Kearny.
Ryon, R. F., Pub. Serv. Co. of No. Ill., Blue Island, Ill.
Samson, I. H., Columbia Univ., N. Y. City.
Sanders, E. R., Travelers Broadcasting Serv. Corp., Hartford, Conn.
Schwab, C. J., McCarthy Bros. & Ford Co., Buffalo, N. Y.
Seal, P. W., United Elec. Lt. & Pwr. Co., N. Y. City.
Seely, R. K., 1011 5th St., Bremerton, Wash.
Seltzer, J. P., 16 Island Ave., Fairfield, Me.
Shaffer, W. E., South Canaan Telephone Co., Gravity, Pa.
Shields, C. B., Union Switch & Signal Co., Swissvale, Pa.
Sievers, J. F., United Elec. Lt. & Pwr. Co., N. Y. City.
Skeats, A. E., 743 Scotland Rd., Orange, N. J.
Slater, R. R., 802 S. Fife St., Tacoma, Wash.
Smedberg, M. W., Bd. of Pub. Utilities, Jamestown, N. Y.
Smith, E. G., 1608 Taylor Ave., Utica, N. Y.
Smith, J. W., Canadian Genl. Elec. Co., Toronto, Ont., Can.
Spencer, D. B. B., Universal High Pwr. Telephone Co., Seattle, Wash.
Stem, E. S., Jr., Alderson, Pa.
Strahm, R. W. No. Illinois Coal Corp., Wilmington, Ill.
Streed, E. R., Delaware Pwr. & Lt. Co., Wilmington.
Surline, J. E., Box 775, Laramie, Wyo.
Sutt, E., Southern Bell Tel. & Tel. Co., Louisville, Ky.
Tamm, E. S., Univ. of Mich., Ann Arbor.
Thomas, K. F., Perkasie Silk Mills, Perkasie, Pa.
Thompson, W. G., Jr., P. O. Box 43, Napa, Calif.
Van Osdol, R. L., 304 Lincoln Way East, Morrison, Ill.
Vaughan, D. C., Potomac Elec. Pwr. Co., Washington, D. C.
Vogel, C. P., 808 S. 15th St., Newark, N. J.
Wagner, H. A., Natl. Transit Pump & Machine Co., Oil City, Pa.
Wagner, H. M., Mass. Inst. of Tech., Cambridge.
Walworth, C. B., Jr., Genl. Elec. Co., Bridgeport, Conn.
Webber, W., Cia Mexico de Petrolso El Aguila, Mexico D. F., Mexico.
Wells, R. G., Aledo, Ill.
Westesen, H. C., Olathe, Colo.
White, C. J., Jr., Callaways Mills, LaGrange, Ga.
White, W. T., U.S. Coast & Geodetic Survey, El Paso, Texas.
Wigton, W. B., Carnegie Inst. of Tech., Pittsburgh, Pa.
Williams, C. L., Forester, Ark.
Williams, G. K., Cornell Univ., Ithaca, N. Y.
Woodson, T. T., 71 E. Lane Ave., Columbus, Ohio.
Works, L. J., The Detroit Edison Co., Mich.
Woundy, I. F., Department of Public Works, Brooklyn, N. Y.
Wright, A. K., Harvard Engg. School, Brookline, Mass.
Yancey, L. C., Chiriqui Land Co., Puerto Armuelles, Rep. de Panama.
Ziegler, T. E., Milford, Pa.
177 Domestic

Foreign

Blangsted, W. E., Triumvirato 2351, Buenos Aires, Arg., S. A.
Greenwell, R., Pub. Wks. Dept., Bombay, Auckland, N. Z.
Hailey, G., (Member) The Hongkong Elec. Co., Ltd., Hongkong, China.
Inocencio, D., La Carlota Sugar Central La Carlota, Occidental Negros, Philippine Islands.
Johnstone, A., Metropolitan-Vickers Elec. Co., Trafford Park, Manchester, Eng.
Kulasekharan, C. R., Corp. of Madras, Madras, India.
Lindorf, L. S., Bol Kommunisticheskaia 7 Kv. 1, Moscow 4, U.S.S.R.
Lloyd, H. S., Metropolitan-Vickers Elec. Co., Ltd., Trafford Park, Manchester, Eng.
Mathur, B. S., Marwar Elec. Sup. Co., Jodhpur (Rajputana), India.
Moore, J. A., (Member), Posts & Telegraphs Dept., Penang, Straits Settlements.
Nason, P. E., 50th Observation Squadron, Luke Field, T. H.
11 Foreign

Engineering Literature

Among the new books received at the Engineering Societies Library, New York, during December are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface or text of the book in question.

CAR BUILDERS' CYCLOPEDIA of American Practice, 1931. Compiled and edited for the Am. Ry. Assn.-Mech. Div. 13 ed. N. Y., Simmons-Boardman Pub. Co., 1932. 1260 p, illus., 12x9 in., cloth, $5.00; lea., $7.00. A standard work of reference on design, construction, and maintenance of freight and passenger cars. Gives a comprehensive picture of current practice on American railroads. This edition has been brought thoroughly up-to-date by deleting obsolete matter and adding developments since the edition of 1928.

Der CHEMIE-INGENIEUR. By A. Eucken and M. Jakob. Band 2, Pt. 1. KONTROLL- und REGULIEREINRICHTUNGEN. By P. Gmelin and J. Krönert. Leipzig, Akademische Verlagsgesellschaft, 1932. 208 p., illus., 10x7 in., cloth, 18.60 rm. This book, which forms part of a comprehensive work on chemical engineering, is to acquaint the reader with the instruments and methods used to record and control manufacturing operations. Various types of recording and metering devices, mechanical and electrical, are described, together with alarms, automatic regulators, distant recorders and other instruments.

ELEKTROTECHNIK, Einführung in die Starkstromtechnik. (Sammlung Göschen 657.) By I. Herrmann. Berlin and Leipzig, Walter de Gruyter & Co., 1932. 118 p., illus., 6x4 in., cloth, 1.62 rm.—This volume attempts to survey the whole field of electric power generation and distribution presenting concisely, an interesting description of the main features of power plants, distributing networks, and switch gear.

ECONOMICS OF CONSTRUCTION MANAGEMENT. By J. L. Harrison. Chicago, Gillette Pub. Co., 1932. 330 p., illus., 8x6 in., cloth, $3.75. The author of this work, who is connected with the Div. of Mgmt. of the U.S. Bureau of Public Roads, discusses the economics of management upon the basis of his studies for the bureau and his experience as supervisor and engineer-in-charge of construction. The contractor will find the book helpful and practical. Accounting, cost control, production, labor, materials, operating expenses, depreciation, etc., are treated.

DIE ELEKTRISCHE KRAFTÜBERTRAGUNG. V. 2. By H. Kyser. 3 ed. Berlin, Julius Springer, 1932. 490 p., illus., 10x6 in., cloth, 34 rm. In the second volume of this treatise on electric transmission, design and construction of transmission lines are comprehensively treated. Overhead and underground lines are considered, both from the electrical and mechanical points of view.

ELEKTRIZITÄT unter TAGE. (Elektrizität in industriellen Betrieben, v. 9.) By W. Philippi. Leipzig, S. Hirzel, 1932. 191 p., illus., 10x7 in., paper, 15.80 rm. Discusses the use of electricity in mines for lighting, haulage, cutting, hoisting, etc. Provides information upon the machinery used for these purposes, upon wiring and switchgear, and upon the dangers peculiar to underground work. Of interest to mine superintendents and electrical engineers.

GESCHICHTLICHE EINZELDARSTELLUNGEN aus der ELEKTROTECHNIK. ed. by Elektrotechnischen Verein. Bd. 4. Die Entstehung der internationalen Masse der Elektrotechnik, by W. Jaeger. Berlin, J. Springer, 1932. 101 p., illus., 10x6 in., cloth, 9 rm. The establishment of international electrical units first received consideration at the Paris Electrical Congress of 1881, and has been receiving constant attention from international committees since that time. A comprehensive account of the way in which our units have been evolved.

GMELINS HANDBUCH der ANORGANISCHEN CHEMIE. System-Nummer 59: EISEN. Teil A, Lieferung 4. By Deutsche Chemische Gesellschaft. Berlin, Verlag Chemie, 1932. 259 p., illus., 10x7 in., paper, 41 rm. This installment of the Gmelins Handbuch devoted to iron, prepared by Dr. R. Durres, director of the Institute of Ferrous Metallurgy at Charlottenburg, treats of the manufacture of wrought-iron and steel. The puddling process and the crucible process are described briefly yet adequately, while the Bessemer open-hearth and electric processes are treated at length. Copious bibliographies are provided for each topic.

HANDBUCH der GEOPHYSIK. Edited by B. Gutenburg. Band 9, Lieferung 1: Der Aufbau der Atmosphäre; Die Schallausbreitung in der Atmosphäre, by B. Gutenberg; Wärmehaushalt der Stratosphäre. pt. 1, by J. Tichanowski, pt. 2, by R. Mügge. Berlin, Gebrüder Borntraeger, 1932. 171 p., illus., 11 x 7 in., paper, subscrip. price 24 rm.; single price 36 rm. These monographs form the first part of a comprehensive summary of our knowledge of atmospheric physics. The structure of the atmosphere, the propagation of sound, and the phenomena of heat absorption and radiation in stratosphere are discussed and the available numerical data presented.

MAN and METALS. By T. A. Rickard. 2 v. N. Y. & Lond., McGraw-Hill Book Co. (Whittlesey House), 1932. 1068 p., illus., 9x6 in., cloth, $10. A history of mining, from the earliest times to the present, which shows the part mining has played in the development of civilization. Man's struggle to master the mineral resources of the world is carefully developed, and students of mining, history, and society will find the work useful.

MECHANICAL TESTING. V. 1. Testing of Materials of Construction. (D.U. Technical Series.) By R. G. Batson and J. H. Hyde. 2 ed., N. Y., E. P. Dutton & Co., 1931. 465 p., illus., 9x6 in., cloth, $6.50. Is intended to inform engineers, manufacturers, and students concerning conditions governing the testing of structural materials, giving particulars about the standard testing plant and its limitations, and information that will enable them to interpret correctly the results of tests. Has been revised to conform with the specifications of the British Engg. Standards Assn., and the chapters on fatigue and hardness testing and testing at high temperatures have been enlarged.

National Research Council. HIGHWAY RESEARCH BOARD. PROCEEDINGS 11th Annual Meeting, Washington, D. C., Dec. 10–11, 1931. Pt. 1. Reports of Research Committees and Papers, 443 p.; Pt. 2. Report of Investigation Upon Use of Rail Steel Reinforcement Bars in Highway Construction, 91 p., 1932. Illus., 10x7 in., paper, $2.00. The principal item in this volume is the report of an extensive investigation of the use of steel rail reinforcement bars in highway construction. Reports are presented of the research committees and a number of technical papers dealing with problems of highway finance, transportation, design, materials, construction, maintenance, and traffic.

THEORY of ELECTRIC and MAGNETIC SUSCEPTIBILITIES. By J. H. Van Vleck. Oxford, Eng., Clarendon Press; N. Y., Oxford Univ. Press, 1932. 384 p., illus., 10x7 in., $7.50.—Present the quantum-mechanical theory of electric and magnetic susceptibilities. The author first considers the classical theory, after which the difficulties and inadequacies of the older quantum theory are discussed. He then elucidates the present theory and considers its correspondence with the available experimental data on susceptibilities.

Industrial Notes

Westinghouse Active in Air-Conditioning Field.—Recent announcements tell of the formation of a new Air-Conditioning Department of the Westinghouse Electric & Manufacturing Company which will coordinate its various existing activities and project its future activities in this field. The company's interest in air-conditioning extends back over a considerable period and includes physiological work on comfort conditions, such as that on effects of radiant heat in its research laboratories as well as actual experimental installations of equipment. At the present time commercial equipment either now is, or soon will be available for railway car cooling; room cooling for homes, offices, and shops; low temperature radiation heaters, and steam operated refrigeration equipment for commercial and industrial applications. Among the interesting developments being carried on which have not yet reached a commercial state is that of the reversed refrigeration cycle for winter heating, and which also can be used for summer cooling as well. The plans of the Air-Conditioning Department are intended to make Westinghouse an important factor in the air-conditioning field aside from large centralized plant installations.

New G-E Circuit Breaker.—A new line of circuit breakers, rated 15, 25, and 34.5 kilovolts, is announced by the General Electric Company. These breakers are equipped with oil-filled bushings of a new type, for potentials up to 34.5 kilovolts. By utilizing the oil-blast principle of circuit interruption, the breakers operate in eight cycles. They are designated Type FHKO-339, for indoor and outdoor service, and have interrupting ratings from 500,000 to 1,500,000 kva. Breakers are of the round-tank construction (one per pole). The oil-blast principle involves forcing oil through a definite channel into the arc path, preventing the arc from restriking after a current zero.

Pipe Ventilated Motor.—The Ideal Electric & Mfg. Co., Mansfield, O., announces a new motor designed for unusually severe service where exposed to high temperature, dust-laden atmospheres, etc., or where totally enclosed motors are recommended because of fire hazards. This pipe-ventilated motor can be used in place of the totally enclosed motor, effecting a considerable saving. The new motor is a totally enclosed polyphase, squirrel cage induction type, ventilation being supplied by a large fan drawing in clean air at one end and discharging the warm air at the other end. The air intake opening leads to a handy source of clean cool air and the outlet opening may be piped wherever desired. These motors are supplied to meet all torque and inrush classifications for both squirrel cage and slip ring induction motors from 1 to 200 hp.

Westinghouse Awarded Large Contract in West.—A contract amounting to nearly $110,000 for three 5000-kva synchronous condensers and insulators has been awarded the Westinghouse Electric and Manufacturing Company by the Metropolitan Water District of Southern California. The equipment will be installed on a temporary power line running from Los Angeles to the Colorado River at Parker Dam. The transmission line is being erected to supply power for the building of an aqueduct which, when completed, is expected to provide the supply water for Los Angeles, and nearby municipalities.

New Magnet Wire.—Vega refractory (Chromoxide) insulated wire is a new development in the magnet wire field. The insulation consists of a refractory chromium compound which is produced by the reaction of chromium oxide and an inorganic binding material applied to the wire at a high heat in combination with a water-insoluble organic binding material which is used for structural purposes. The insulation is thin and flexible, having a space factor comparable to enameled wire, thus allowing a large number of turns in a small space when compared with other refractory insulations, as asbestos. Cotton or silk, when used as a covering where an unusual amount of abuse is encountered from automatic machine winding, will not slip and spread as much as do these textile coverings when wound on enameled wire.

The insulation has high thermal conductivity and allows a rapid transmission and dissipation of heat to the exterior. Coils wound with Vega refractory (Chromoxide) insulated wire, either plain or textile covered, will withstand continuous operation at high temperature limits, without short circuiting between turns. The manufacturers specify that the insulation shall withstand continuous operation at Class "B" (A.I.E.E. Standards) temperature as contrasted with Class "A" (enamel, cotton, or silk) insulation. A feature of the insulation is its adaptability with flat type conductors. Vega refractory insulated ribbon or flat wire affords an important saving in space. The cost of this heat resistant insulated wire is only slightly above enamel wire and only a fraction of the cost of other refractory insulations. The wire is made and sold by American Enameled Magnet Wire Company of Port Huron, Michigan.

Trade Literature

Traffic Signals.—Bulletin GEA-1680, 20 pp. Describes G-E Novalux Traffic Signals. General Electric Co., Schenectady, N. Y.

Vitrohm Resistor Units.—Bulletin 507, 16 pp. Describes Vitrohm radio products, principally vitreous enameled resistor units. Ward Leonard Electric Co., Mt. Vernon, N. Y.

Circuit Breakers.—Catalog 6, 4 pp. Describes a complete line of indoor type, common frame, oil circuit breakers from 200 to 2000 amperes and from 750 to 15,000 volts. Roller-Smith Co., 12 Park Place, New York.

Carbon Brushes.—Catalog 3211, 12 pp. Describes a complete line of carbon brushes in sizes specified for motors of various prominent manufacturers. Helwig Co., 3466 So. 13th St., Milwaukee, Wis.

Midget Megger Tester.—Bulletin 1350, 4 pp. Describes a new, small "Megger" insulation tester. This instrument is of pocket size and weighs 3 pounds. The range is up to 20 megohms and the device itself generates testing current at 500 volts, requiring no other source of current supply. James G. Biddle Co., 1211 Arch St., Philadelphia, Pa.

Trench Guards.—Bulletin, 4 pp. Describes a new trench guard for protecting open street excavations, ditches, etc. These guards are made of rust-proof malleable iron, are easily assembled in a complete, unbroken fence around any shaped opening, and can be conveniently packed in small space for transportation. They have fittings to hold securely both lanterns and flags. The Cleveland Trencher Co., 20100 St. Clair Ave., Cleveland, O.

Instruments.—Bulletin, 10 pp. Describes a new line of "Steel-Six" portable instruments the outstanding features of which are steel cases shielding the mechanism against the effect of external magnetic influences; unusually long scales ($5^3/_{16}$ in.); high accuracy; open and well-lighted dials; fusing when desired; a very complete line, comprising direct current ammeters, milliammeters, voltmeters, millivoltmeters, and voltammeters and alternating current ammeters, milliammeters, voltmeters, single and polyphase wattmeters, frequency meters, and power factor meters. Roller-Smith Co., 12 Park Place, New York.

Rubber Bearings for Hydraulic Turbines.—Bulletin, 18 pp., "Cutless Rubber Guide Bearings As Applied to Hydraulic Turbines," written by R. E. B. Sharp, hydraulic engineer, Baldwin-Southwark Corporation, I. P. Morris division, Philadelphia, Pa. Subjects treated include: "Oil Lubricated Metal Bearings Present Difficulties Not Found in Water Lubricated Bearings"—"Early Uses of Rubber Guide Bearings in Hydraulic Turbines"—"Rubber Bearings Resist Abrasion to a Remarkable Degree"—"Spiral Grooved Type Bearings"—"Segmental Type Bearings"—"Installation of Rubber Bearings in Existing Turbines"—"Amount of Lubricating Water Required for Cutless Rubber Bearings"—"Shaft and Shaft Sleeves"—"Cutless Rubber Bearings Capable of Sustaining Heavy Shafts With Minimum Oscillation"—and "Uses of Cutless Bearings Increasing." There are now 42 hydraulic turbines with Cutless Rubber Bearings in operation, with an aggregate capacity of 514,010 horsepower. Shaft diameters vary from 7 to $31^1/_2$ inches. The B. F. Goodrich Company, Akron, Ohio.